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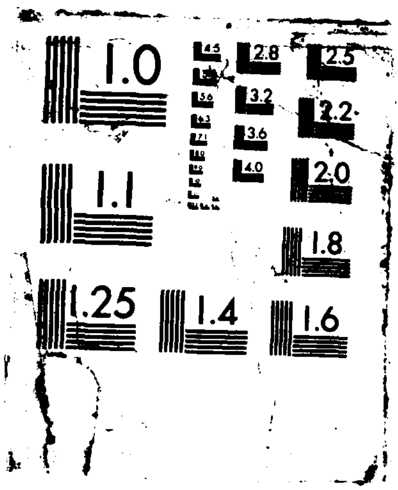
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WHOI-87-50



# Woods Hole Oceanographic Institution

WOODS HOLE OCEANOGRAPHIC INSTITUTION
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## Real-Time Environmental Arctic Monitoring (R-TEAM) Interim Report



Edited by

Alessandro Bocconcelli

November 1987

Technical Report

Funding was provided by the Office of Naval Research under contract Number N00014-86-C-0135.

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# Real-Time Environmental Arctic Monitoring (R-TEAM)

## Interim Report

Edited by

Alessandro Bocconcelli

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543



November 1987

## Technical Report

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**Approved for Distribution:**

Albert J. Williams III

**Albert J. Williams III, Acting Chairman**
Department of Ocean Engineering

## ACKNOWLEDGMENTS

We, the engineers, technicians, and support personnel who have designed, built, tested, deployed and successfully recovered the first R-TEAM prototype, want to thank Dr. R. Spindel for his inspiring leadership throughout the program and Dr. T. Curtin for his constant interest and support.

The work reported hereafter is sponsored by the Office of Naval Research under Contract Number N00014-86-C-0135.

This report has been coauthored by:

| | |
|---|---|
| H. Berteaux | WHOI |
| A. Bocconcelli | " |
| P. Clay | " |
| K. Doherty | " |
| J. Hager | Defense System Inc. |
| E. Mellinger | WHOI |
| J. Valdes | " |

TABLE OF CONTENTS PAGE

LIST OF FIGURES PAGE



LIST OF TABLES

## EXECUTIVE SUMMARY (H.O. Berteaux)

This interim report describes the development and testing of the R-TEAM system from the initial concept studies to the actual deployment and recovery of a working prototype at Site D, 39°N, 70°W (June 2 to August 3, 1987). The essential points of this development effort are hereafter summarized.

The R-TEAM mooring is ~~specifically~~ designed to collect oceanic environmental data in ~~the~~ Arctic regions and to transmit these data to shore on a daily basis via ARGOS satellite telemetry. ~~To this end~~ an ascent module comes to the surface once a day and transmits directly to ARGOS (ice free surface) or indirectly through a relatively close-by MF receiver station (ice covered surface). When not transmitting the module remains in its rest position most of the time, well away from the surface, thus diminishing the risks of damage at the ice interface. The R-TEAM's design life ~~of the R-TEAM system~~ is one year in situ. The mooring must be capable of deployment in depths of up to 4500 ~~meters~~ and must be able to withstand a maximum current speed of 2 knots at the surface.

At an early stage two different transit options were considered: ~~a~~ winch/pop-up buoy and a variable ballast elevator. ~~The latter~~ seemed more directly compatible with our existing capabilities and easier to develop within the time and budget constraints of the project. Following this concept evaluation, a design effort was initiated and pursued to develop the electrical and mechanical components required to satisfy the R-TEAM system specifications. This development effort was shared with Defense Systems Inc. (DSI) of McLean, VA., who designed and built the UHF and MF transmitters, antennae, and associated electronics.

Important and novel components developed during the period include:

- R-TEAM controller which performs all timing and control functions required in the operation of the mooring and also acts as the central data acquisition and in situ processing computer (acquisition of sensor data, buffering, and forwarding to transmitter).
- R-TEAM power system, valve driver, MF power supply.
- MF and ARGOS transmitters and matching submersible antennae.
- All software for above electrical functions.
- SAIL/FSK pre-processor modules to permit interrogation by and data transfer between the controller and the sensors (current speed and direction, depth, water temperature and conductivity).
- Ambient noise sensor.
- Special electromechanical cables and highly reliable cable connectors to interconnect the sensors and the controller.
- Variable buoyancy system, control valves, and high pressure gas source (Liquid $Co_2$).
- Rigid, buoyant umbilical cable to provide electrical, mechanical, and pneumatic connection between the gas and power storage housed in the mooring's main sphere and the ascent module.

All these components and their integration into subsystems were carefully and systematically bench tested, pressure tested, and near shore tested prior to their deployment at sea.

The prototype mooring ~~(Figure 1)~~ was deployed in 2700 ~~meters~~ at ~~Site~~ D on June 2, 1987 and entirely recovered 62 days later. By and large this experimental deployment was very successful but ~~and~~ instructive. It showed that with the help of exacting mooring line measurement and accurate navigation, the R-TEAM upper sphere could be set at its prescribed depth with a precision of ± one half percent of total depth. It demonstrated concept feasibility and confirmed design soundness, with the module ascending 80 times in 40 days, and transmitting according to computer controlled schedule, otherwise resting at its computer anticipated depth. Records of currents, sensor depths, module depth, and gas and power consumption, will provide the data base for engineering evaluation and possible modifications and improvements for the actual next R-TEAM system which will be deployed in the Arctic in early September of 1988.

The test also revealed two deficiencies which need to be ~~and will be~~ corrected. The first is an interruption in the collection of the data from the sensors inserted in the mooring line. The communication link between the controller in the ascent module and the sensors on the line, which functioned perfectly before, during, and immediately after deployment, failed soon thereafter during the test. Upon recovery, the controller and the communication link again functioned correctly, and as of this writing it continues to do so while cycling in a test mode on the WHOI dock. The cause of the failure is at this time unknown; possible causes which will be investigated further include intermittent electronic component failure, intermittent connector contact, or a well-hidden software bug in the controller. Since nearly identical communication technology has been employed without incident since 1984 (RELAYS program), it is not expected that major redesign will be required to correct this problem.

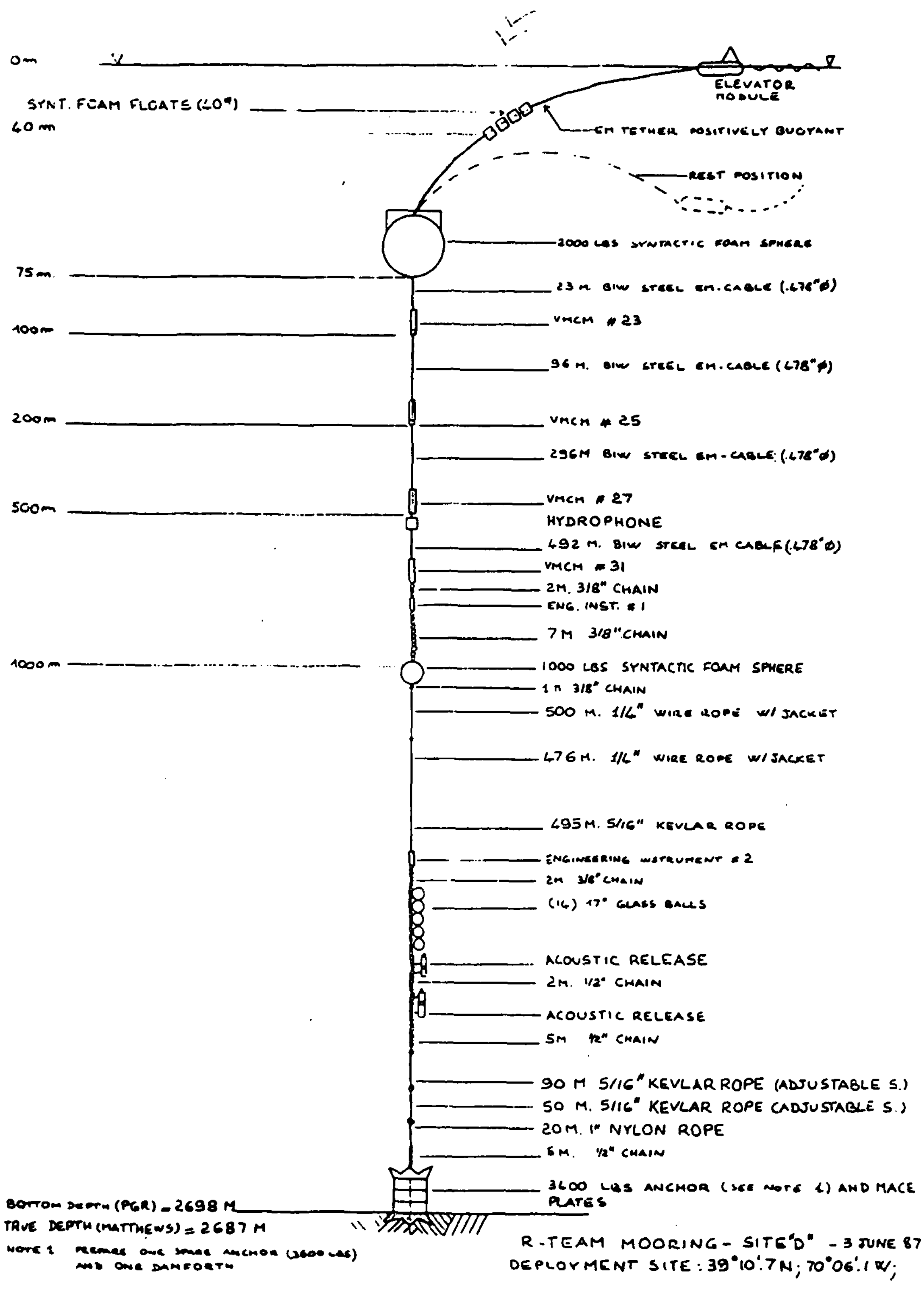



Figure 1. Site 'D' Prototype Mooring.

The second is a failure of the oil filled high pressure valve which ceased to operate after 40 days on station, thus disabling the ascent mode of the elevator. The cause of this failure appears to be a leakage of high pressure $CO_2$, due to a defective O-ring, which eventually created enough pressure to rupture the diaphragm. Sea water then filled the solenoid cavity, shorting the main power supply. The power was thus cut off, forcing the ascent module to stay in its rest position until mooring recovery. Corrective steps, described in some detail in the report, include a new O-ring design, and a pressure relief valve, or simply a watertight pressure case around the valve. Both options will be systematically investigated and extensively tested.

The operational R-TEAM mooring will be deployed approximately 150 miles NW of Ny Alesund, Spitzbergen, in early September 1988. A special, shore based radio station will monitor the MF "through the ice" link and will relay the data to ARGOS as needed. The mooring will be recovered in the spring of 1989. To reach this objective, the following tasks remain to be performed:

- Assessment and correction of prototype deficiencies.
- Demonstration of current meter telemetry to ARGOS satellite (WHOI dock).
- Refurbish MF transmitter (DSI).
- Full telemetry (MF & ARGOS) tests. MF antenna pattern/range final tests (Woods Hole - WHOI/DSI).
- Arctic deployment planning: Site, schedule, ship, handling gear, shore station, scientific party.
- Environmental data.

- Arctic mooring design/procurement/assembly. New mooring design. New ascent module (controls, body). Upward Looking Sonar (ULS). New cable assemblies. Additional software. Current Meter (CM) preparations.
- Arctic precruise testing. (3) groups of test to be performed in winter months in waters proximate to Woods Hole: ascent module performance, transmitters and computer performance, and complete actual system test (WHOI/DSI).
- Shipping to Tromso (Norway).
- Install shore station (DSI).
- Deployment (WHOI/DSI).

The time table for these different tasks, shown in Figure 2 concludes the Executive Summary.

<u>**KEY PERSONNEL** (November 1986 to October 1987)</u>

| | |
|---|---|
| R. Spindel | Principal Investigator |
| M. Briscoe | Scientific Advisor |
| H.O. Berteaux | Project Manager |
| A. Bocconcelli | Project Engineer (Moorings) |
| P. Clay | Research Associate (Testing, Sea Operations) |
| K. Doherty | Mechanical Engineer (Variable Ballast System) |
| J. Hager (DSI) | Electrical Engineer (Satellite Telemetry) |
| E. Mellinger | Electrical Engineer (Controller/Computer) |
| J. Valdes | Electrical Engineer (Sensors) |

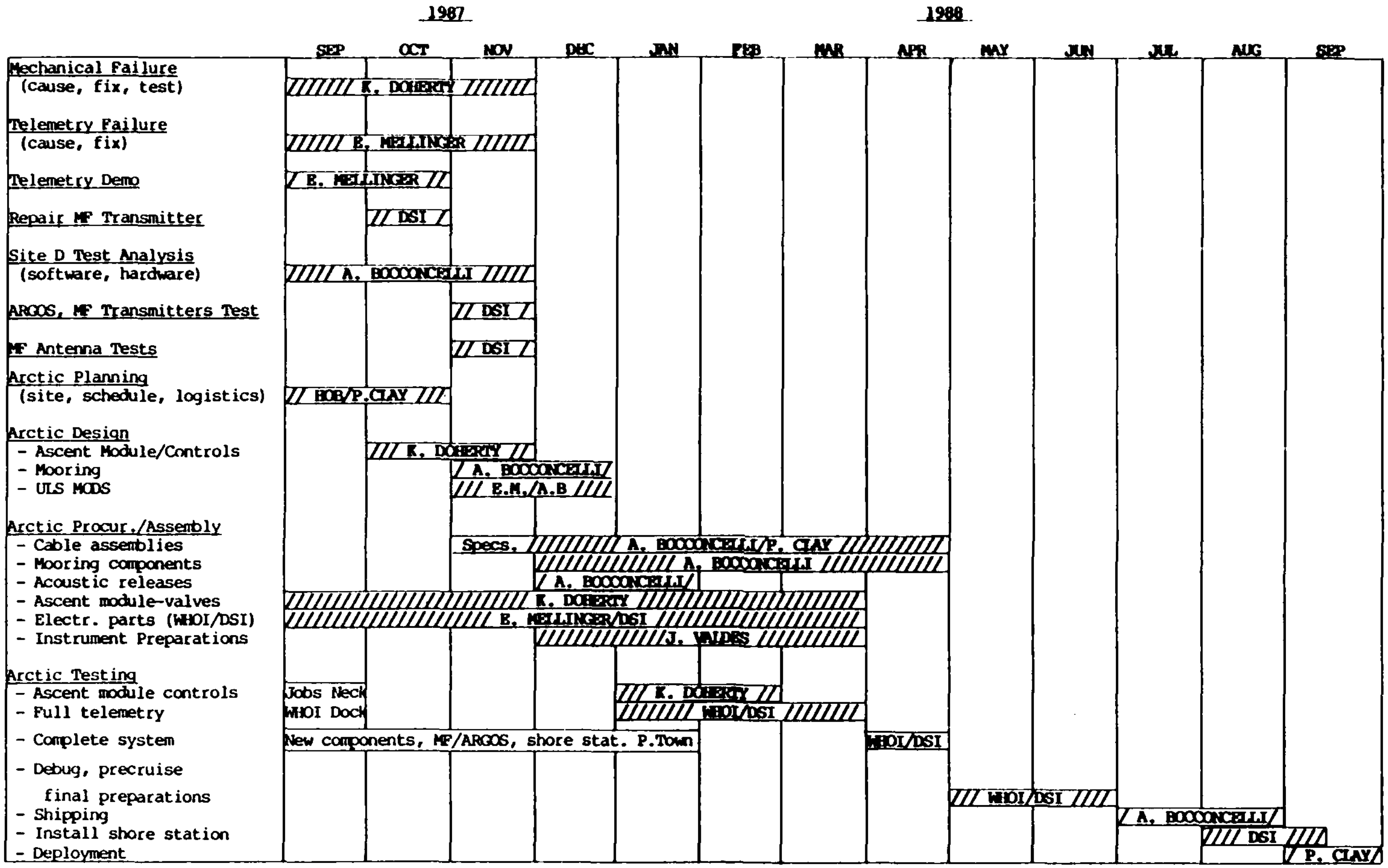



Figure 2. R-TEAM Preparation and Arctic Deployment Time Table.

## 1. INTRODUCTION.

This report is a summary of the R-TEAM project development from the conceptual/design stage to the deployment and recovery of the system prototype at Site D (39°10'N - 70°06'W) from June 2 to August 3, 1987 in 2700m of water depth.

The R-TEAM mooring has been specifically designed to collect environmental data in the Arctic region and to transmit these data to shore on a daily basis via ARGOS satellite. The mooring must be capable of deployment in depths up to 4500m and must be able to withstand a maximum current speed of 2 knots at the surface. To minimize the risks of damage at the ice interface, the transmitters remain at a safe distance (200 meters or so) from the surface most of the time, ascending once a day for a short period of transmission. At an early stage two modes of transit were considered: a pop-up buoy operated by an underwater winch (Figure 3) and a variable ballast elevator (Figure 4). The two options were compared and their features rated as shown in Table 1.

**Table 1**
**Comparison of Winch and Variable Ballast Transit Option**

| Salient Points | Winch | Variable Ballast |
|---|---|---|
| Straightforwardness | X | |
| Reliability | | X |
| Assurance to perform in high currents/storms | | X |
| Initial cost | | X |
| Reproduction cost | | X |
| Long range benefits | | X |
| Reuse cost | | X |
| Amount of testing needed | X | X |
| Endurance | X | |
| Confidence to have ready by Spring '87 | X | X |

The variable ballast elevator seemed more compatible with our existing capabilities and more likely to fit the timing and budget constraints. A predecessor system (Reference 1) which had been successfully deployed was also an encouraging factor.

## 2. SCHEDULE.

The period from June to December 1986 was spent considering different design options and performing computer parametric studies of mooring performance. The schedule for the acquisition, development, and integration of the various R-TEAM system components and their testing prior to deployment at sea is shown in Table 2.

**Table 2**
**R-TEAM Preparation Schedule**

| | 1987 JAN/FEB | MARCH | APRIL | MAY | |
|---|---|---|---|---|---|
| ELEVATOR MODULE | Design | | Fabricate | dock test | prep. for sea |
| UMBILICAL | | Procure | | dock test | prep. for sea |
| CONNECTION OF UMBILICAL | Design | Fabricate | | | prep. for sea |
| ANTENNA (HF) | Procure | Ship | | dock test | prep. for sea |
| CONTROL COLLAR | Procure | | | | prep. for sea |
| SPHERE | Procure | | | | prep. for sea |
| E/M CABLE ASSEMBLIES | | Procure | tank test | dock test | prep. for sea |
| VMCM | Fabricate | bench test with controller | | dock test | prep. for sea |
| HYDROPHONE | | Fabricate | bench test | dock test | prep. for sea |
| WIRE ROPE | Procure | | | | prep. for sea |
| RELEASES | | | Preparations for sea | | |
| ELECTRONICS (WHOI) | | bench test VMCM | | dock test | prep. for sea |
| CONTROLLER | Design | Assembly | bench test | dock test | |
| SENSORS | Design | Assembly | bench test | dock test | |
| POWER PACK | Procure | | | dock test | |
| VALVE DRIVER | Design | Assembly | bench test | dock test | |
| ELECTRONICS (DSI) | Fabricate | Ship | bench test | dock test | prep. for sea |

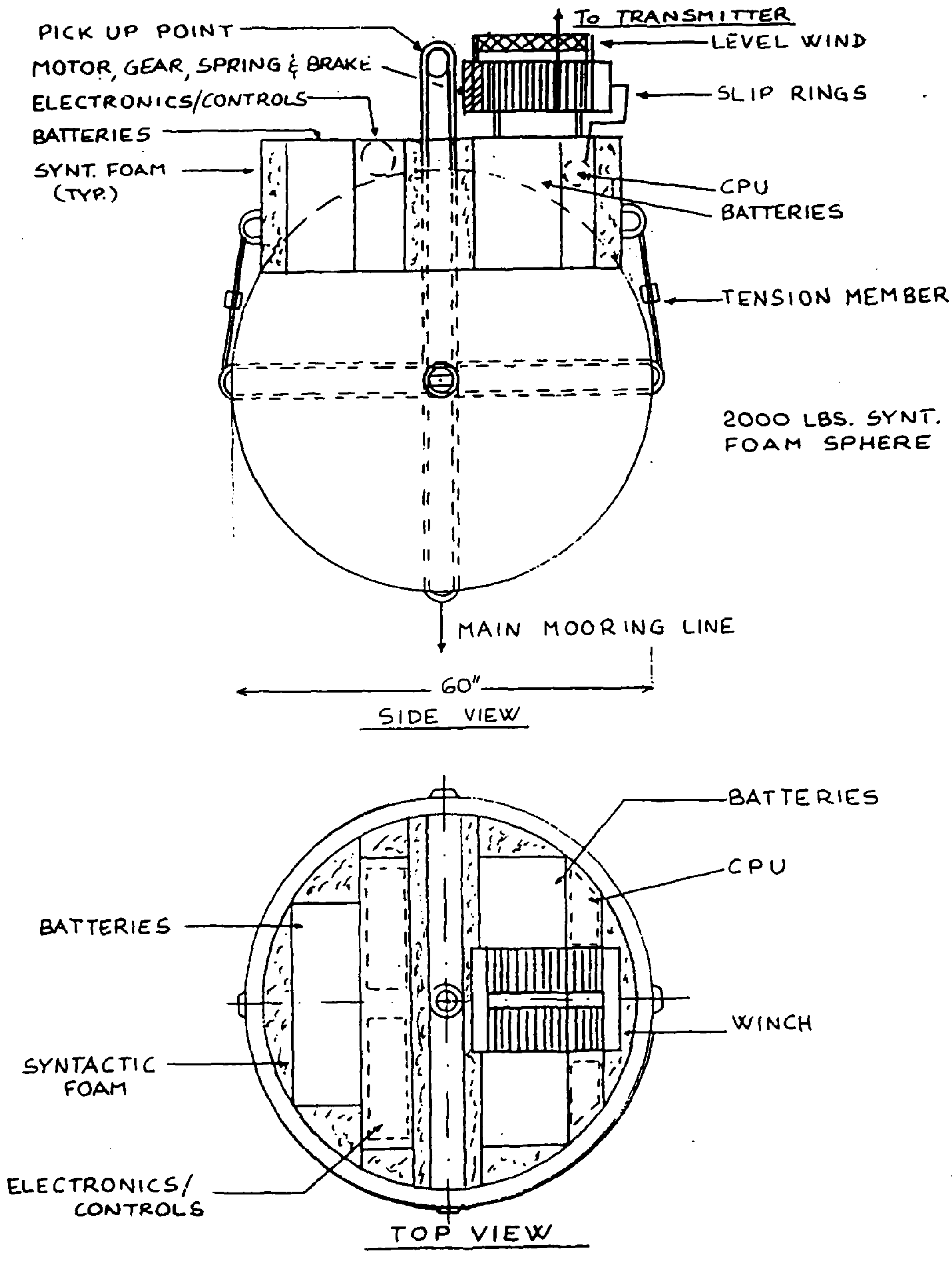



**Figure 3. Winch/Pop Up Buoy. Concept.**

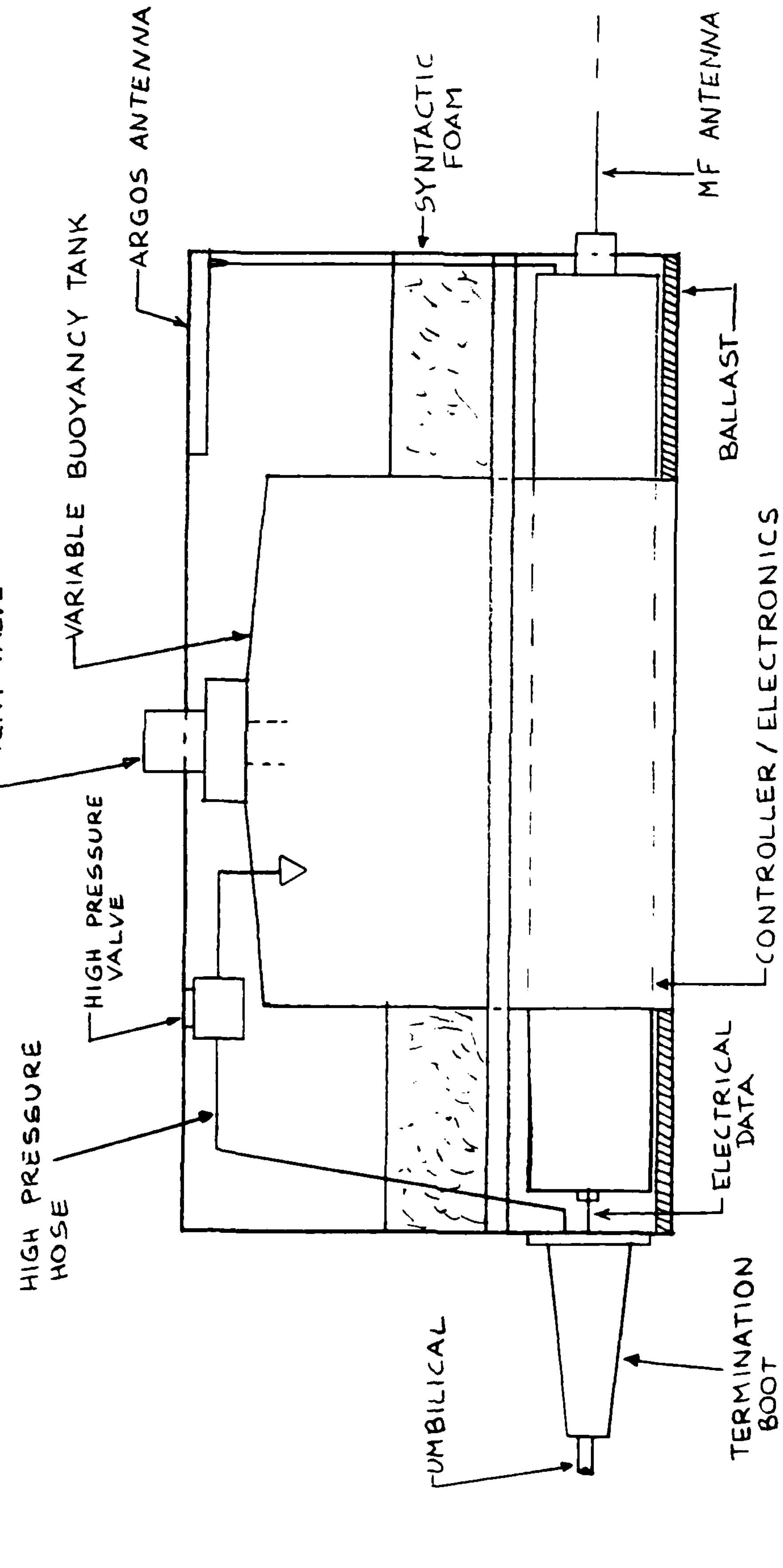



**Figure 4. Variable Ballast Elevator. Concept.**

## 3. MAIN COMPONENTS.

The system's main components, schematically depicted in Figure 5, include the following:

**. Transmitters and antennae:** The UHF and MF transmitters, antennae and associated electronics were built by Defense Systems Inc. Depending on sea surface condition (ice or not) environmental data are relayed on a daily basis to ARGOS satellite through UHF or MF radio transmission.

**. Variable ballast ascent module:** The variable ballast ascent module consists of a fiberglass frame which houses the controller, valve driver and the variable buoyancy tank. Environmental data from mooring sensors are collected and stored by the controller which also governs the daily ascent, data transmission, and descent cycle.

**. Umbilical:** Purge gas, data and electrical power are carried through the umbilical cable from the mooring collar to the ascent module. Diameter and buoyancy of the umbilical cable are determined by parametric computer analysis in order to obtain the best buoyancy to drag ratio.

**. Mooring control collar:** Built of syntactic foam it houses gas storage tanks and main battery pressure cases. The complete structure is positively buoyant and fits on top of a 2000 lb. subsurface buoy.

**. E/M Cable:** The electromechanical cable (E/M) connects the mooring sensors together and carries the collected environmental data through SFK/SAIL loop from the bottom VMCM to the mooring control collar.

**. Sensors:** Four VMCMs and one hydrophone are included in the R-TEAM deep water prototype mooring. Current, conductivity, temperature and ambient noise data are collected and sent to the controller for daily telemetry. As a fallback position, the same data are internally recorded.

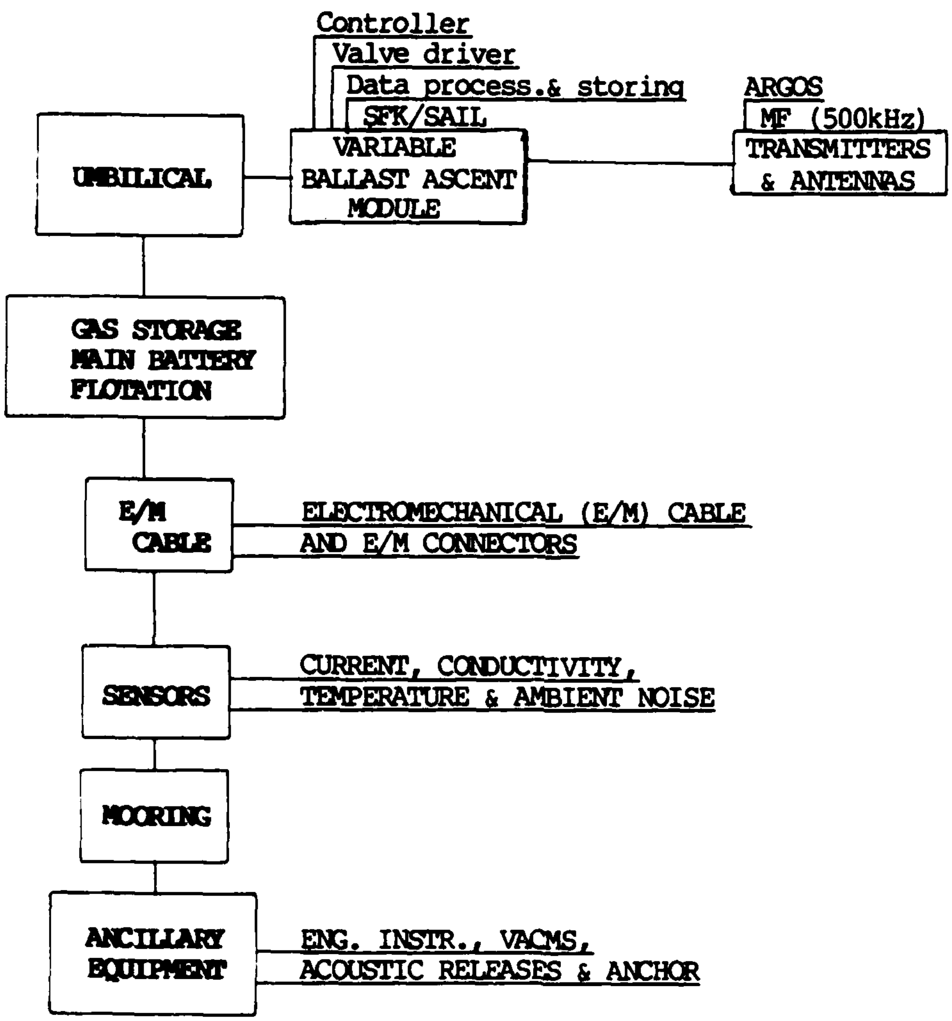



**Figure 5. R-TEAM Main Components. Schematic.**

**. Mooring:** The mooring line consists of 1/4" torque balanced jacketed wire rope, located in the Fishbite Zone (up to 2000m depth) and 1/4" Kevlar rope below. Various lengths of galvanized steel chain connect ancillary equipment to the mooring line.

**. Ancillary equipment:** Two engineering instruments are located at critical points of the mooring. Tension, tilt, pressure and temperature data are recorded on solid state memory for the duration of the deployment. Two Benthos acoustic releases located at about 170m above the sea bottom allow for a safe recovery of the mooring. A 1000 lb. syntactic foam sphere was inserted at a depth of 1000m to provide added mooring rigidity and reduce the dip of the upper sphere. A 3400 lb. anchor completed the mooring.

## 4. BUOY SYSTEM DEVELOPMENT.

**4.1 Mooring Analysis (A. Bocconcelli).** The mooring design study was divided into three different stages, each focusing on a particular section of the mooring. They can be summarized as follows:

- **Stage I** - subsurface mooring without the umbilical and the elevator module. Mooring analysis was done with the help of the NOYFB computer program.
- **Stage II** - umbilical and elevator module independent of the rest of the mooring. This study was accomplished using DIPPER, a computer program specifically developed and written for R-TEAM.
- **Stage III** - using NOYFB, the results of Stage II were applied to those of Stage I to obtain a mooring configuration which takes into account the drag forces due to the umbilical, elevator module, and MF antenna.

Results obtained for the mooring shown in Figure 1 (Site D) are summarized in Table 3.

**Table 3**
**Computer Prediction for R-TEAM Mooring (Site D)**

| Mooring Component | Depth (m) w/o current | Current Speed (cm/sec) | Depth (m) w/design current | Depth (m) w/design current & drag due to umbilical & elevator |
|---|---|---|---|---|
| | surface | 75.0 | | |
| 2000# buoy | 75 | ---- | 88.3 | 136.4 |
| 1st VMCM | 101.1 | 37.5 | 113.8 | 161.7 |
| 2nd VMCM | 203.3 | ---- | 216.0 | 262.8 |
| 3rd VMCM | 503.9 | 25.0 | 516.1 | 558.5 |
| 4th VMCM | 1000.7 | ---- | 1010.7 | 1041.4 |
| 1000# buoy | 1014.9 | ---- | 1024.8 | 1055.0 |
| Eng. Instr. #2 | 2494.9 | 10.0 | 2495.7 | 2497.7 |

The various lengths of E/M cable, Kevlar rope and wire rope, the amount of flotation needed, the anchor weight and required position of the instruments were determined in Stage III. Using this computer technique, two mooring designs were finalized. One for deployment off the SE shore of Bermuda ($32^{o}13'$N - $64^{o}33'$W), see Figure 6, and one for deployment at Site D (Figure 1).

These designs are similar to the High Performance Oceanographic Mooring (HIPOM) which was successfully deployed during the summer of 1986 in the Gulf Stream (Reference 2). The main difference is the presence of an umbilical cable which connects the 2000 lb. subsurface buoy to the elevator module. The umbilical characteristics were determined in stage II.

An umbilical cable parametric study was done with the computer program DIPPER. Assuming an ascent module of known shape and reasonable surface buoyancy (150 lbs.), the length of umbilical required to bring this

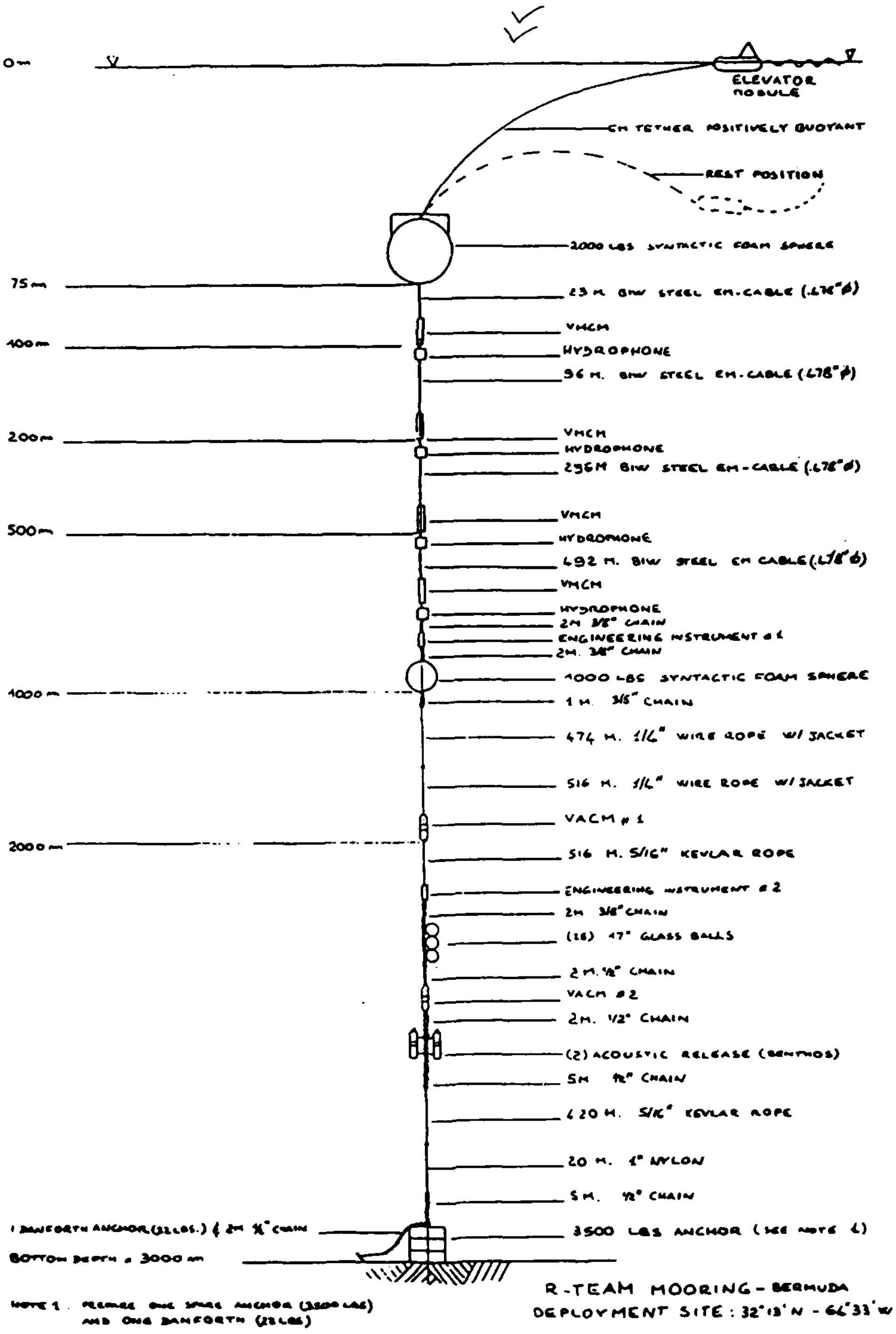



**Figure 6. R-TEAM Mooring for Bermuda Test Site.**

ascent module to the surface with a maximum current of two knots was computer determined. A compromise between length and diameter of the umbilical was achieved in order to optimize the buoyancy versus drag ratio. The resulting characteristics of the R-TEAM umbilical cable were as follows: O.D = 1.5", length = 720', buoyancy = 124 lbs./1000 ft.

In addition to umbilical design, an analysis of the ascent module negative and positive buoyancy requirements had to be made. This was determined by analyzing the zero and maximum current cases using the DIPPER program.

Negative buoyancy is needed to pull down the buoyant umbilical cable after $Co_2$ purging, enabling the module to sink and reach its rest position. Based on the umbilical specifications above, the maximum trim weight was determined to be 73 lbs. for the zero current case. With the 2000 lb. sphere set at a nominal depth of 75 m (246 ft.), the zero current geometry of the umbilical would then be as shown on Figure 7.

Positive buoyancy is needed to bring and maintain the module on the surface. To this end two design constraints had to be considered: The size of the tank which determines the available buoyancy when on the surface, and the amount of gas required to insure surfacing.

The size of the buoyancy tank is dictated by the maximum anticipated current (the stronger the current, the more buoyancy needed to reach and stay on the surface). With the subsurface buoy 75 meters below the surface, and 220 meters of umbilical cable, the minimum amount of buoyancy needed to maintain the ascent module on the surface when subjected to the design current profile shown in Table 3 was found to be 2.15. We selected a tank volume of 2.75 cu.ft. to be on the conservative side.

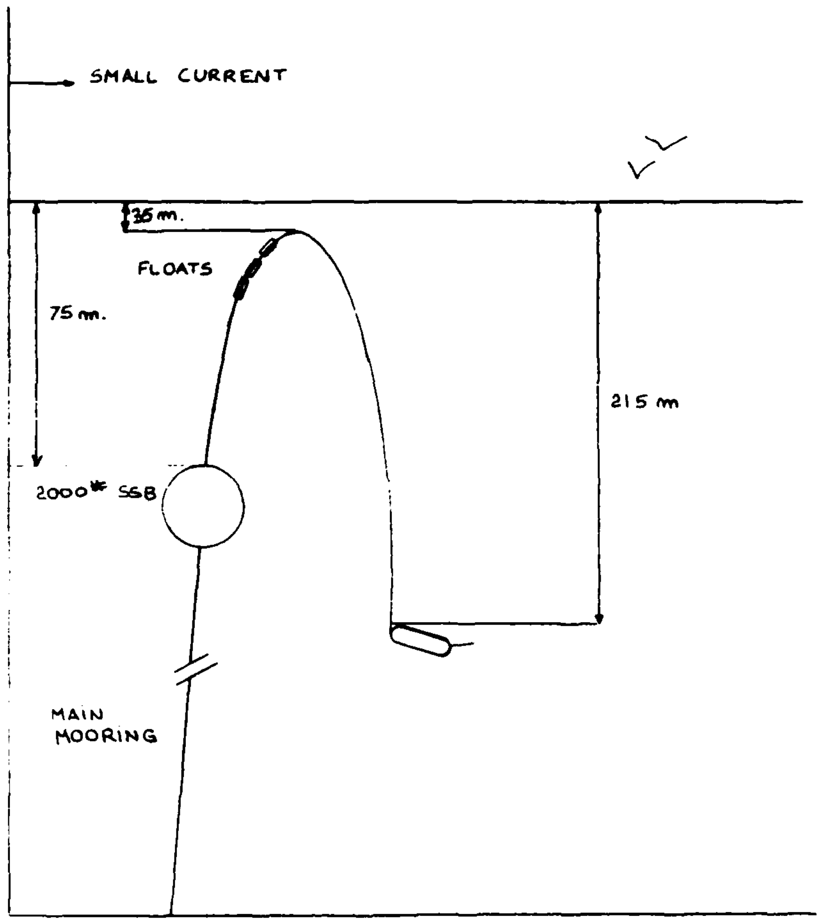



Figure 7. Umbilical Rest Position Geometry (zero current).

The amount of gas required per ascent cycle was determined using the following rationale. Under zero or very small current conditions it would seem that a very small amount of $CO_2$ would be sufficient to initiate and complete the ascent. However, in this case the pull of the buoyant cable decreases as the module ascends by an amount proportional to the length of cable forced back to the surface. Soon an equilibrium would be reached and ascent would stop.

To assess the minimum quantity of $CO_2$ at STP conditions which would be required by the module to surface irrespectively of cable buoyancy losses, a computation had to be made which followed these steps:

1. Assume a loss of cable pull "B" (lbs.)
2. Calculate the corresponding depth "z" reached by the module (ft.)
3. Derive the STP amount G(s) of $CO_2$ (cu.ft.) required to reach that depth, using

$$G(s) = P(z) * G(z)$$

where P(z) = pressure at depth "z" (atmospheres)

G(z) = amount of $CO_2$ @ depth "z" = B/64 (cu.ft.).

Results from this computation procedure are shown in Table 4.

Based on these results a conservative amount of 8 cu.ft. (STP) per ascent was programmed. With 1800 cu.ft. of $CO_2$ stored in the two titanium spheres, this amount would permit 225 ascent cycles. The amount of $CO_2$ allowed to flow at the beginning of ascent, as it expands on the way up, is far in excess of the ballast tank capacity. Some of the $CO_2$ thus has to overflow and escape during the ascent. With proper sensors and algorithm a "smart" ballast system can be devised to reduce or suppress these losses.

**Table 4**
**Buoyancy Requirement Analysis**

| B (lbs) | Z (ft.) | P(z) (ATM) | G(z) (cu.ft.) | G(s) (cu.ft.) |
|---|---|---|---|---|
| 0 | 705 | 22.50 | 0 | 0 |
| 5 | 620 | 19.90 | 0.07812 | 1.5547 |
| 10 | 540 | 17.50 | 0.15625 | 2.7343 |
| 15 | 467.7 | 15.1727 | 0.23437 | 3.556 |
| 20 | 427.4 | 13.9515 | 0.31250 | 4.35984 |
| 25 | 387 | 12.7272 | 0.39062 | 4.9715 |
| 30 | 346.7 | 11.5060 | 0.46875 | 5.393 |
| 35 | 306 | 10.2727 | 0.54687 | 5.7454 |
| 40 | 266 | 9.0606 | 0.62500 | 5.66 |
| 45 | 225.8 | 7.8424 | 0.70312 | 5.5141 |
| 50 | 185.5 | 6.6212 | 0.78125 | 5.1728 |
| 55 | 145.2 | 5.4000 | 0.85937 | 4.64 |
| 60 | 104.8 | 4.1757 | 0.93750 | 3.91 |
| 65 | 64.5 | 2.9545 | 1.01562 | 3.00 |
| 70 | 24.2 | 1.7333 | 1.09375 | 1.8958 |
| 73 | 0 | 1 | 1.140625 | |

**4.2 Mooring Components (A. Bocconcelli).** The mooring components designed, purchased and tested by the WHOI Ocean Structures and Moorings Laboratory (OS&M) are the following:

. Umbilical cable

The criteria adopted for the umbilical design were the following:

a) Minimize drag and maximize buoyancy.

b) Strength not to exceed 3000 lbs. which is much less than the strength of the rest of the mooring line. This would prevent total loss of the mooring in the event that the upper part be caught and dragged away.

c) Fishbite protection, achieved by covering the umbilical with a jacket of Zytel and by placing the air hose and the conductors at the core of the cable.

d) Three watertight conductors to carry signals to the elevator module.

e) 3000 psi hose located at the core of the cable.

These specifications were incorporated in the umbilical cable designed and built by Consolidated Products Corp., CA. Details of the design are shown in Figure 8. The cable was electrically and mechanically terminated at both ends using the termination design shown in Figure 9.

. Umbilical floats

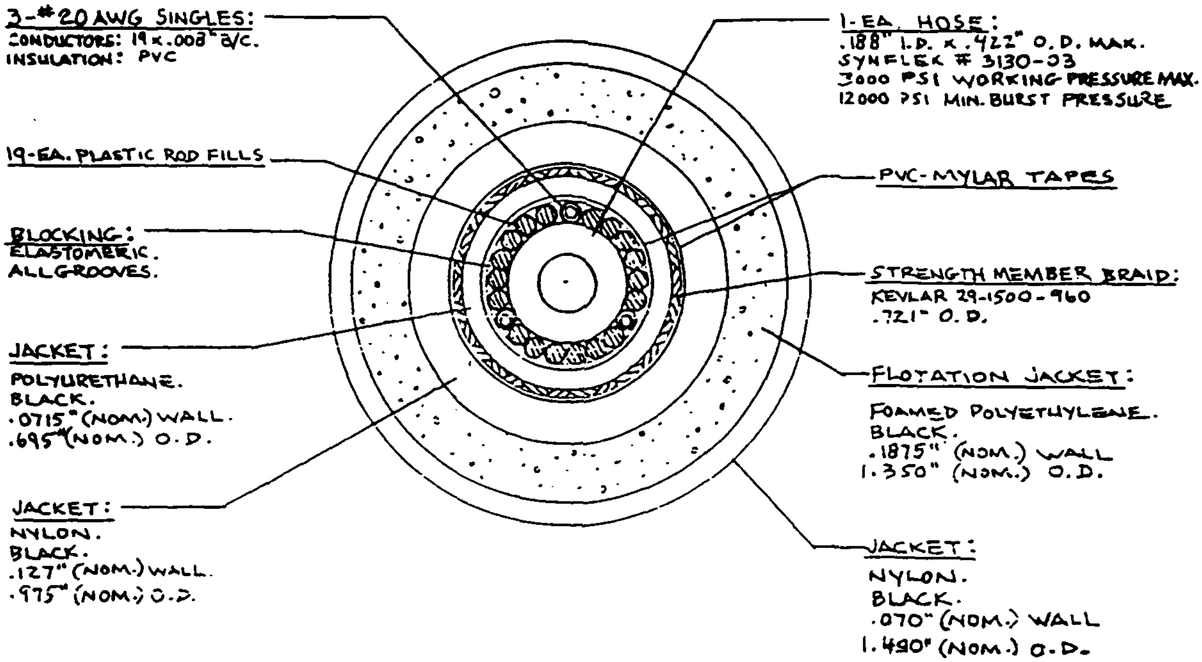
The umbilical floats were designed to provide additional buoyancy to the umbilical without affecting the negative weight needed to sink the variable ballast elevator module (Figure 10). Each float has 2 lbs. of buoyancy and is fixed to the umbilical with heavy duty tie wraps. All the syntactic foam buoys and floats were built to WHOI specifications by Flotation Products, ME.

. 1000 lb. Buoyancy sphere

The 1000 lb. syntactic foam subsurface buoy is the same as the one used for the HIPOM mooring (Reference 2). The control collar, the 2000 lb. and 1000 lb. spheres were built by Flotation Products, ME.

. Battery cases

Two storage cases able to withstand pressure up to 500 psi were designed and built to house the main power pack. Dimensions and special features of these pressure cases are shown in Figure 11.




NOTES:

*1. CABLE WEIGHT PER 1000 FEET:
650# IN AIR
-124# IN SEA WATER.

*2. SPECIFIC GRAVITY: .84

**3. BREAK STRENGTH: 3200 # (NOM.)

**4. MAX. WORKING LOAD: 640 #

**5. MIN. BEND DIAMETER: 48"

* AT ZERO PSI EXTERNAL PRESSURE AND WITH EMPTY HOSE.

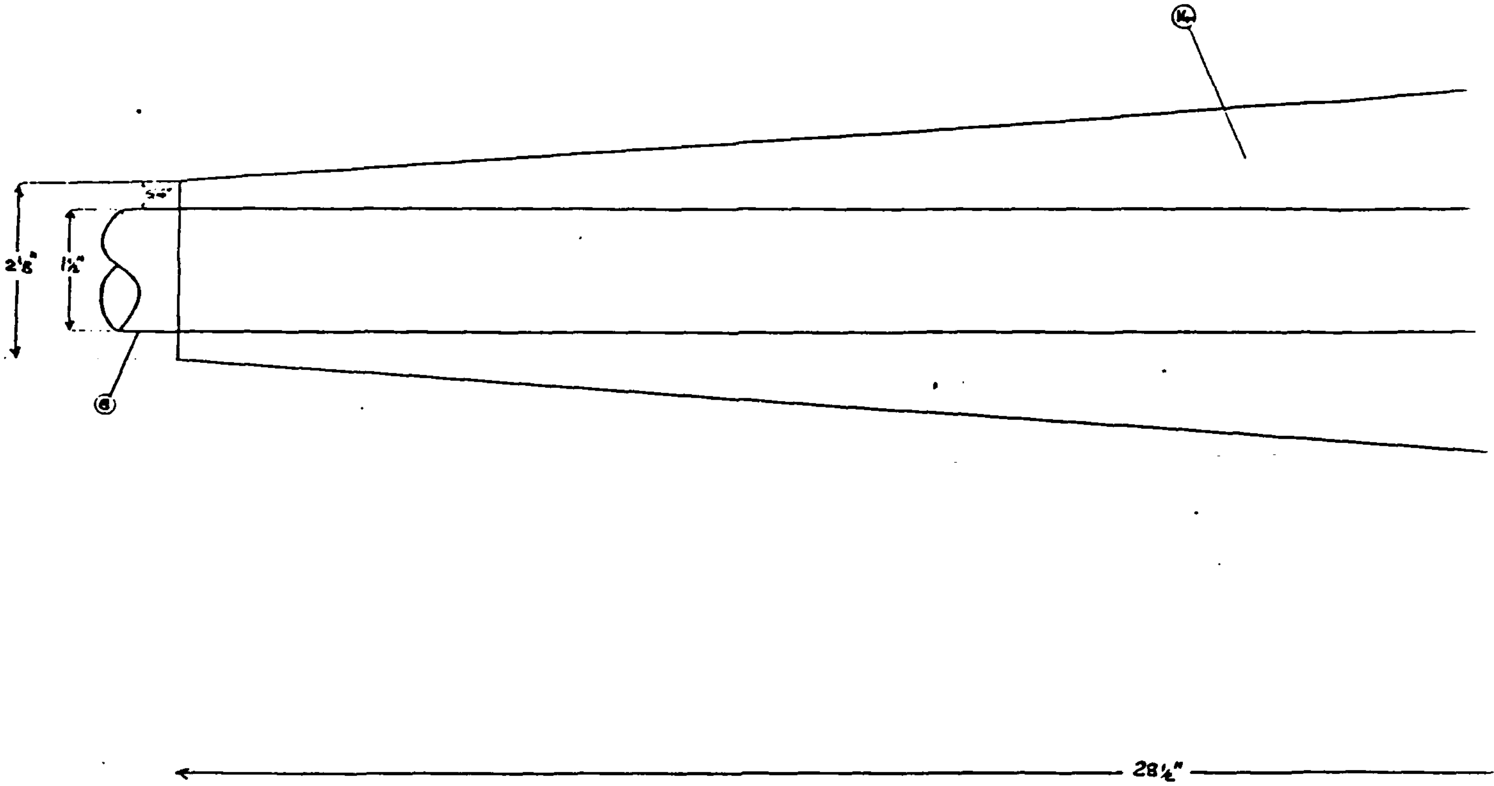
** WITH HOSE PRESSURIZED.

SOUTH BAY CABLE DIVISION
CONSOLIDATED PRODUCTS CORPORATION

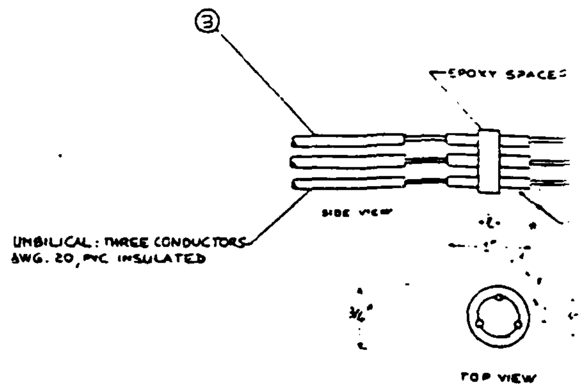
| | | | | | |
|---|---|---|---|---|---|
| DRAWN | Hunt | 1-12-87 | APPROVAL | W.L.T. | 1-13-86 |
| CHECKED | H.M.Tch | 1-13-87 | APPROVAL | | |

CABLE, E.M., SPECIAL PURPOSE — SB-37367

Figure 8. Kevlar Armored Umbilical Cable.




| # | DESCRIPTION |
|---|---|
| 1 | SYNFLEX AIRHOSE, PART NO 3130-03, OD = .420" POLYURETHANE JACKET |
| 2 | BRANTNER PIG TAIL, OD = .230" POLYURETHANE JACKET |
| 3 | (3) CONDUCTORS, SOLDER; SEE DETAIL "A" |
| 4 | KEVLAR STRANDS |
| 5 | POLYURETHANE POUR: TU 79 (W/ KEVLAR STRANDS IN TENSION) |
| 6 | EPOXY POUR: DER 33 (W/ KEVLAR STRANDS IN TENSION) |
| 7 | 2ND POLYURETHANE POUR: TU 79 (W/KEVLAR STRANDS CLIPPED) |
| 8 | UMBILICAL CABLE - OD = 1.490" (NOM) |
| 9 | UMBILICAL: PLASTIC ROD FILLERS |
| 10 | UMBILICAL: CORE POLYURETHANE JACKET: OD = .695" |
| 11 | UMBILICAL: NYLON ZYTEL JACKET OD = .975" |
| 12 | UMBILICAL: FOAMED POLYETHYLENE JACKET OD = 1.350" |
| 13 | UMBILICAL: NYLON ZYTEL JACKET: OD = 1.490" |
| 14 | POLYURETHANE BOOT (75 DUROMETER) TU 79 |
| | |

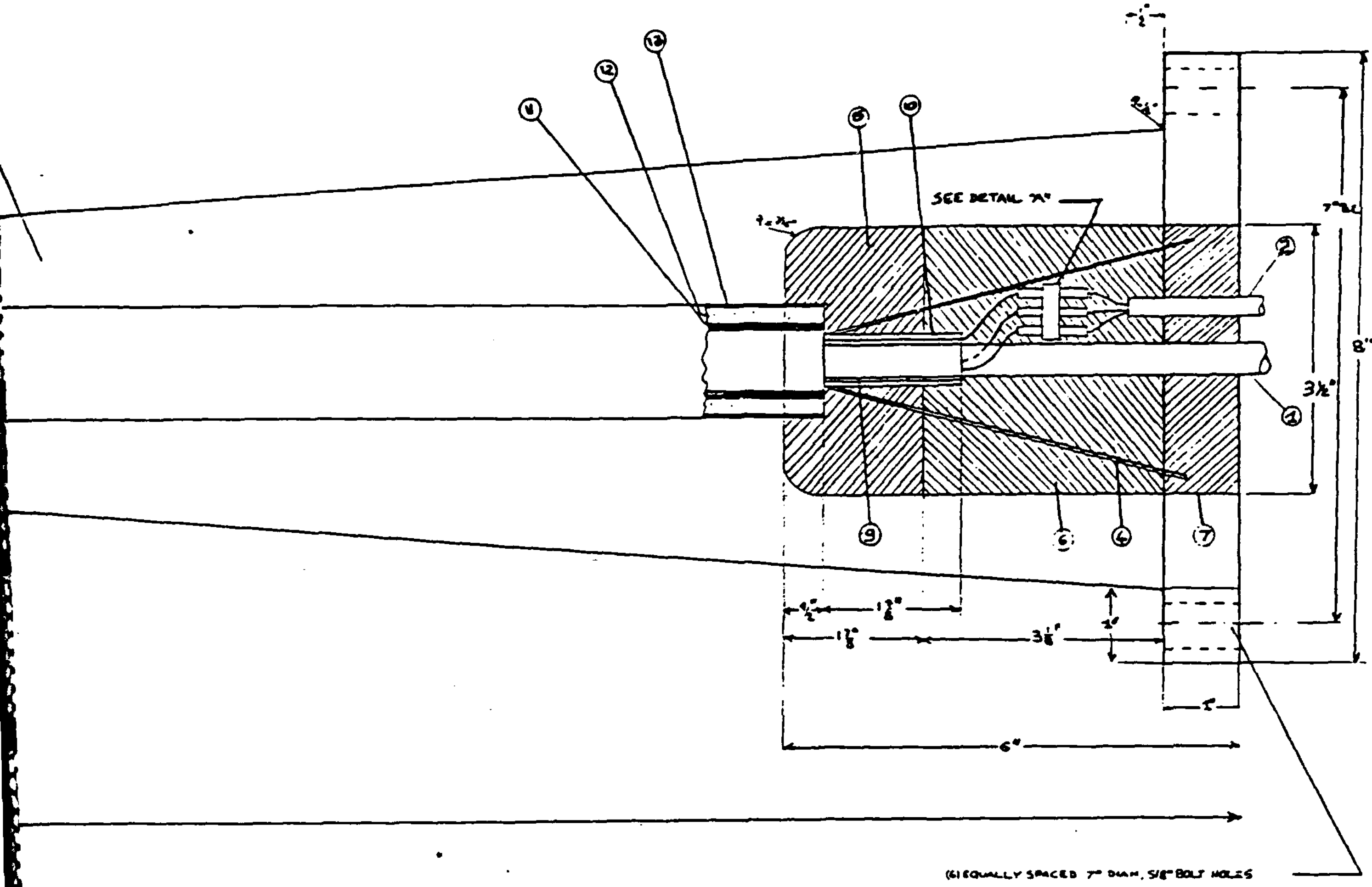


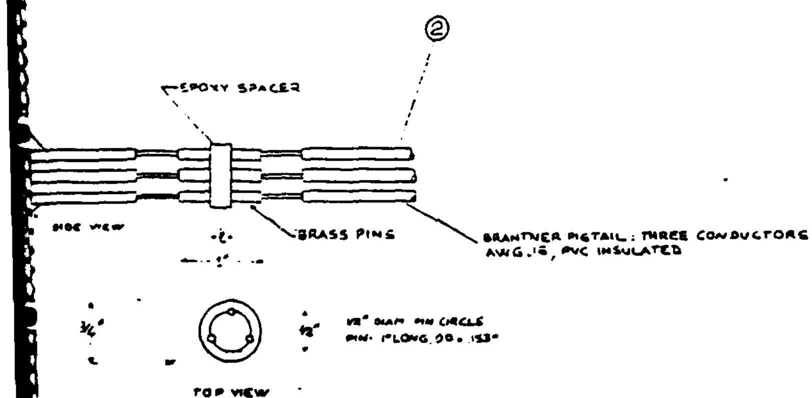

DETAIL "A"

NOTE: UMBILICAL CABLE BY CONSOLIDATED PRODUCTS CORP.
W.H.O.I. P.O. #21166

1 of 2

Figure 9. Umbilical Cable




DETAIL "A"

2 of 2

. Umbilical Cable Termination.

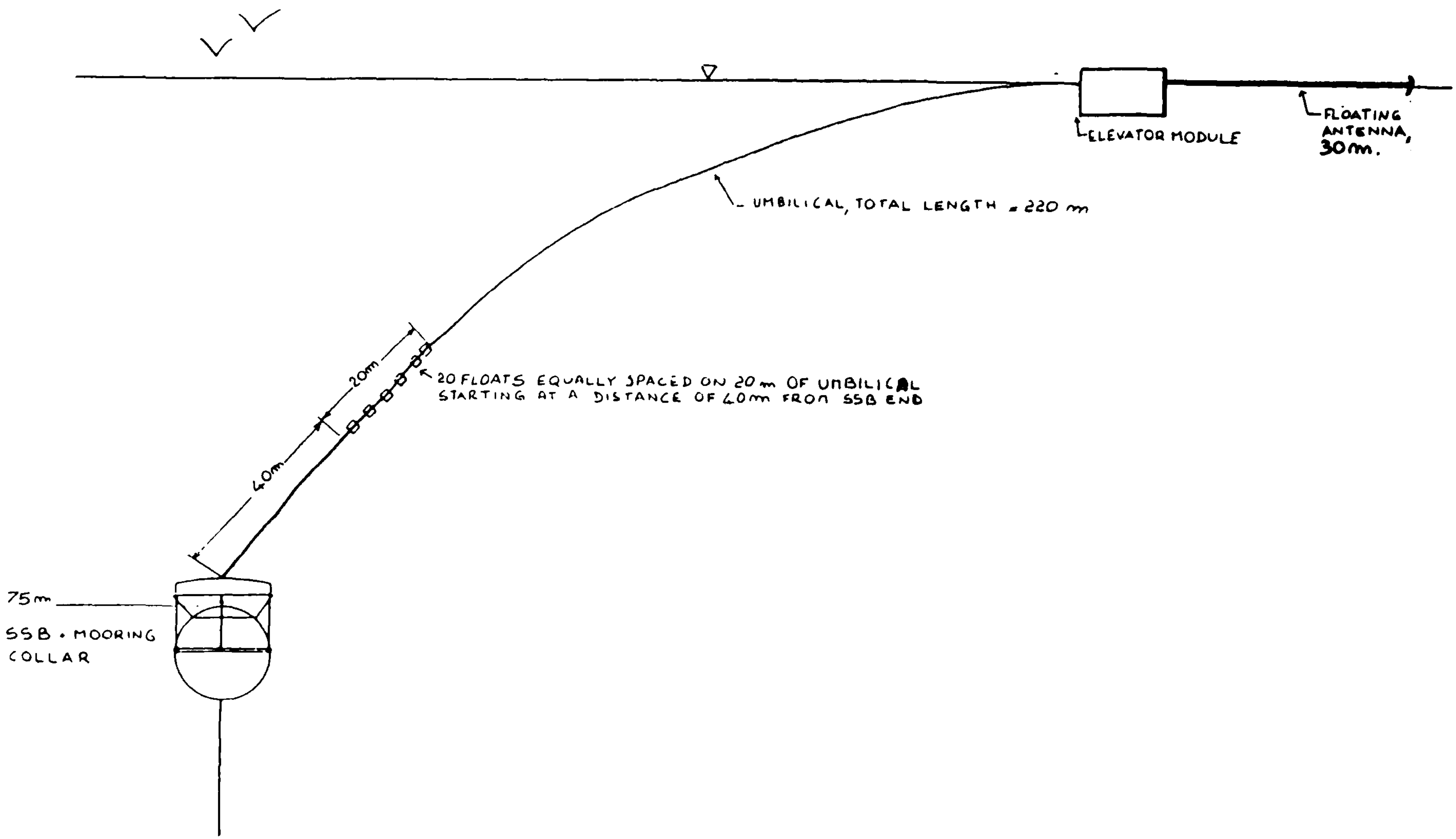
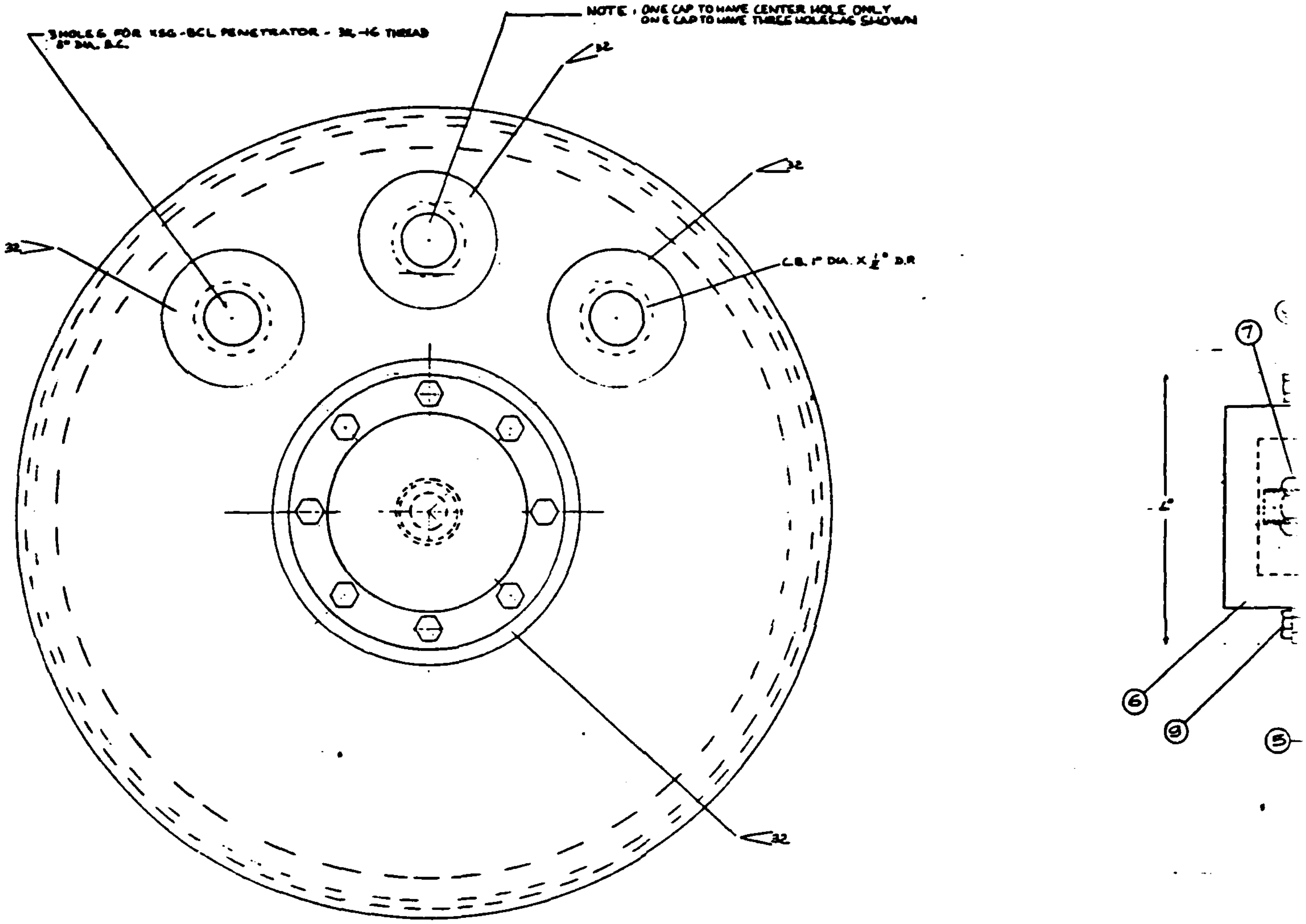


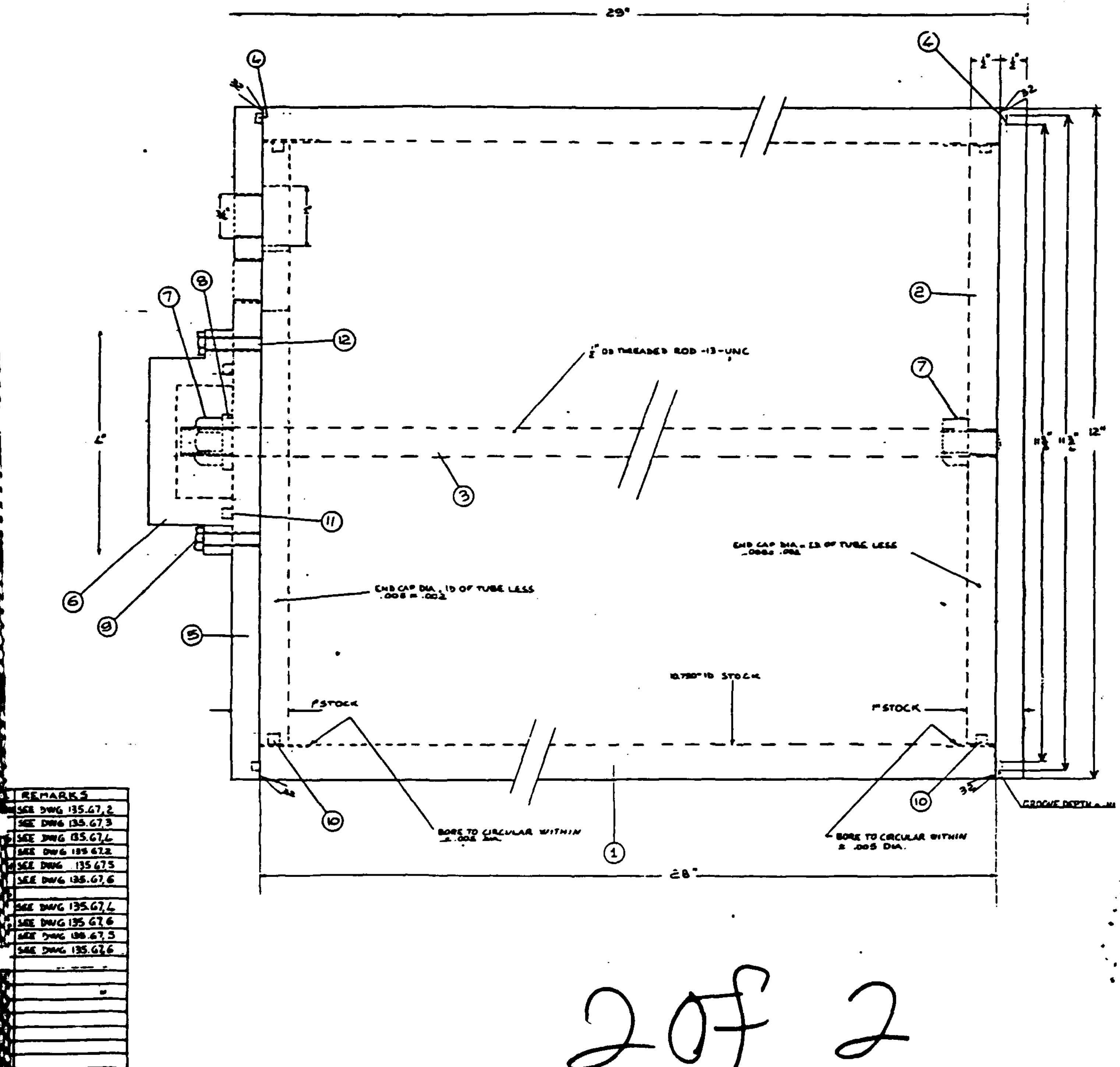

Figure 10. Float Arrangement on Umbilical Cable.




| # | REQD | DESCRIPTION | MAT'L | REMARKS |
|---|---|---|---|---|
| 1 | 2 | ALUMINUM PIPE - OD = 12" - WALL = 5/8" | AL. 6061 | SEE DWG 135.67.2 |
| 2 | 2 | BOTTOM END CAP | " | SEE DWG 135.67.3 |
| 3 | 2 | ROD | SS 316 | SEE DWG 135.67.4 |
| 4 | 4 | "O" RING PARKER 2-276 | | SEE DWG 135.67.2 |
| 5 | 2 | TOP END CAP | AL. 6061 | SEE DWG 135.67.5 |
| 6 | 2 | TOP END CAP BOLT COVER | " | SEE DWG 135.67.6 |
| 7 | 4 | 1/2"-13-HEX NUT | SS 316 | |
| 8 | 2 | DELRIN WASHER | DEL. | SEE DWG 135.67.4 |
| 9 | 8 | 1/4"-20-HEX HEAD SCREW W/ DELRIN WASHER | SS 316 | SEE DWG 135.67.6 |
| 10 | 4 | "O" RING: PARKER 2-275 RADIAL | | SEE DWG 135.67.5 |
| 11 | 2 | "O" RING: PARKER 2-228 | | SEE DWG 135.67.6 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

1 of 2

Figure 11. R-TEAM Batteries P




2 of 2

R-TEAM Batteries Pressure Case.

. Mooring control collar

The mooring collar (Figure 12) was designed in order to house the batteries and the gas storage tanks. The collar fits on top of the standard 2000 lb. syntactic foam sphere and provides enough buoyancy to compensate for the weight of the batteries and titanium sphere storage tanks. The collar dimensions were kept as small as possible in order to both minimize drag and the added buoyancy on top of the sphere, which in turn increases the tension on the mooring.

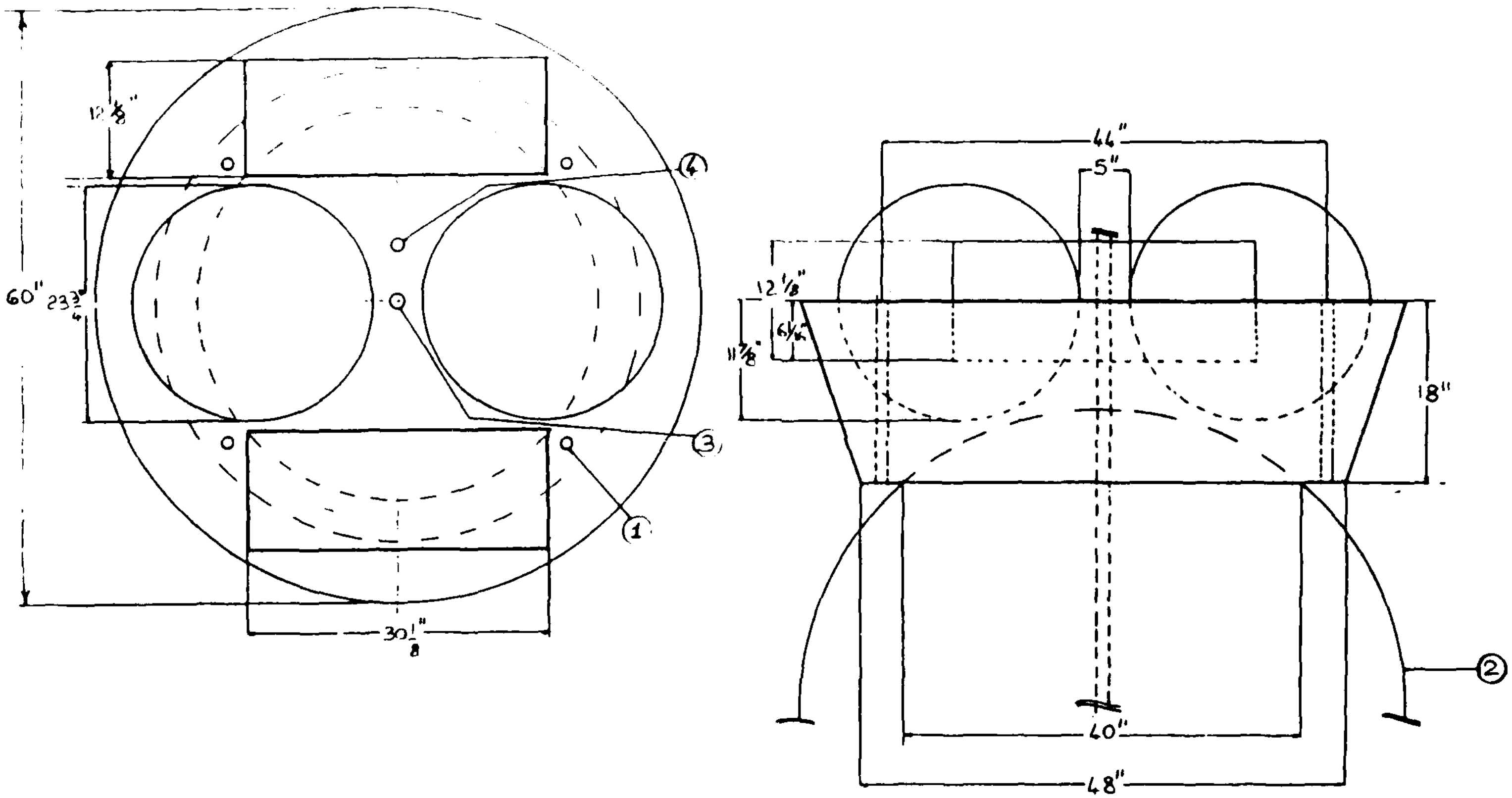
The mooring collar and the 2000 lb. sphere are held together with a rod going through the center of the sphere (Figure 13). The rod also provides an attachment point for the umbilical (upper end) and for the E/M cable (lower end). On the outside, the mooring collar is anchored to the sphere with four lengths of 3/8" chain tensioned by turnbuckles.

A fiberglass shroud was built and installed on top of the mooring control collar in order to protect the wiring between battery cases and piping valves of the $CO_2$ gas system.

. 2000 lb. Buoyancy sphere

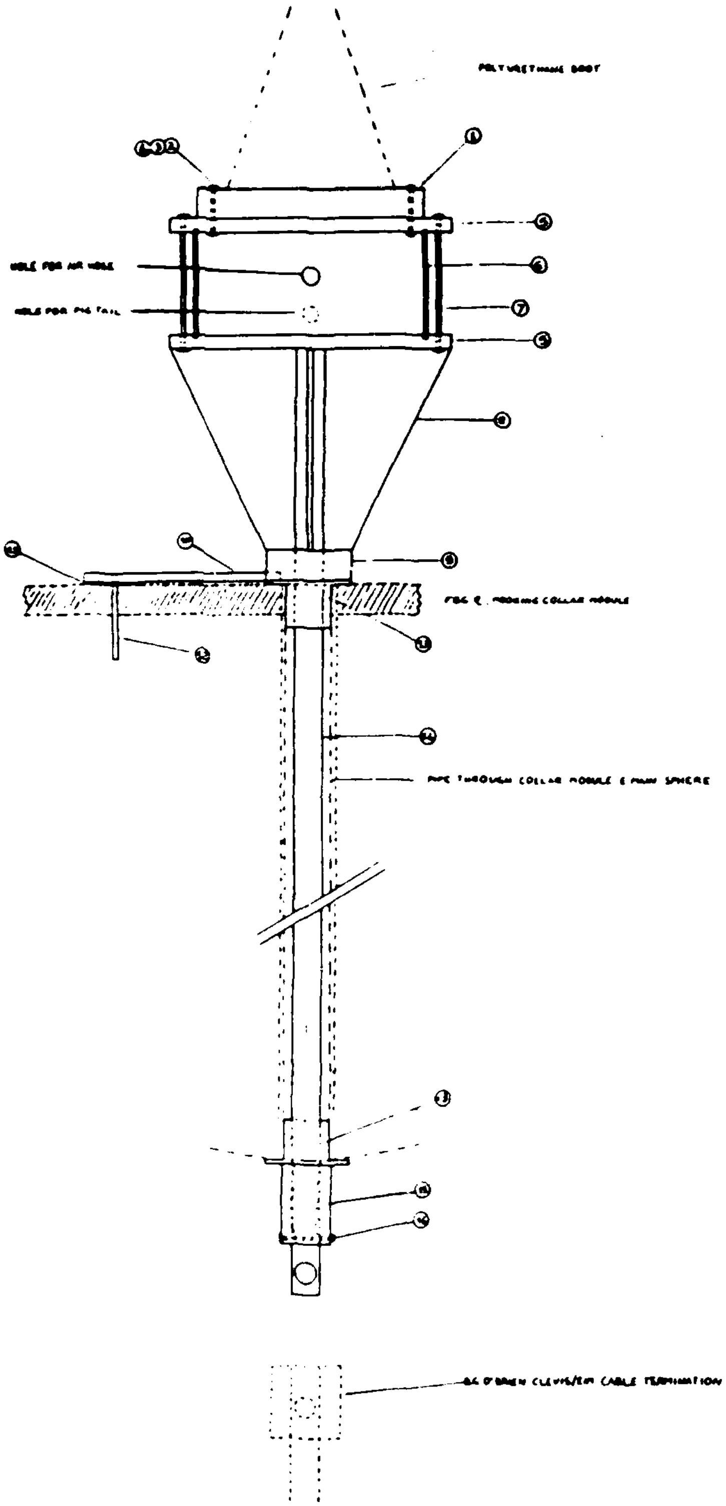
The 2000 lb. syntactic foam buoy was built following a standard design for subsurface buoys. This particular sphere has an additional conduit going from top to bottom in order to feed a pigtail connector from the lower part of the mooring to one of the battery storage cases.

A stainless steel belly band was secured around the sphere to make lifting and deployment operations safer. The mooring control collar and sphere assembly are depicted in Figure 14.



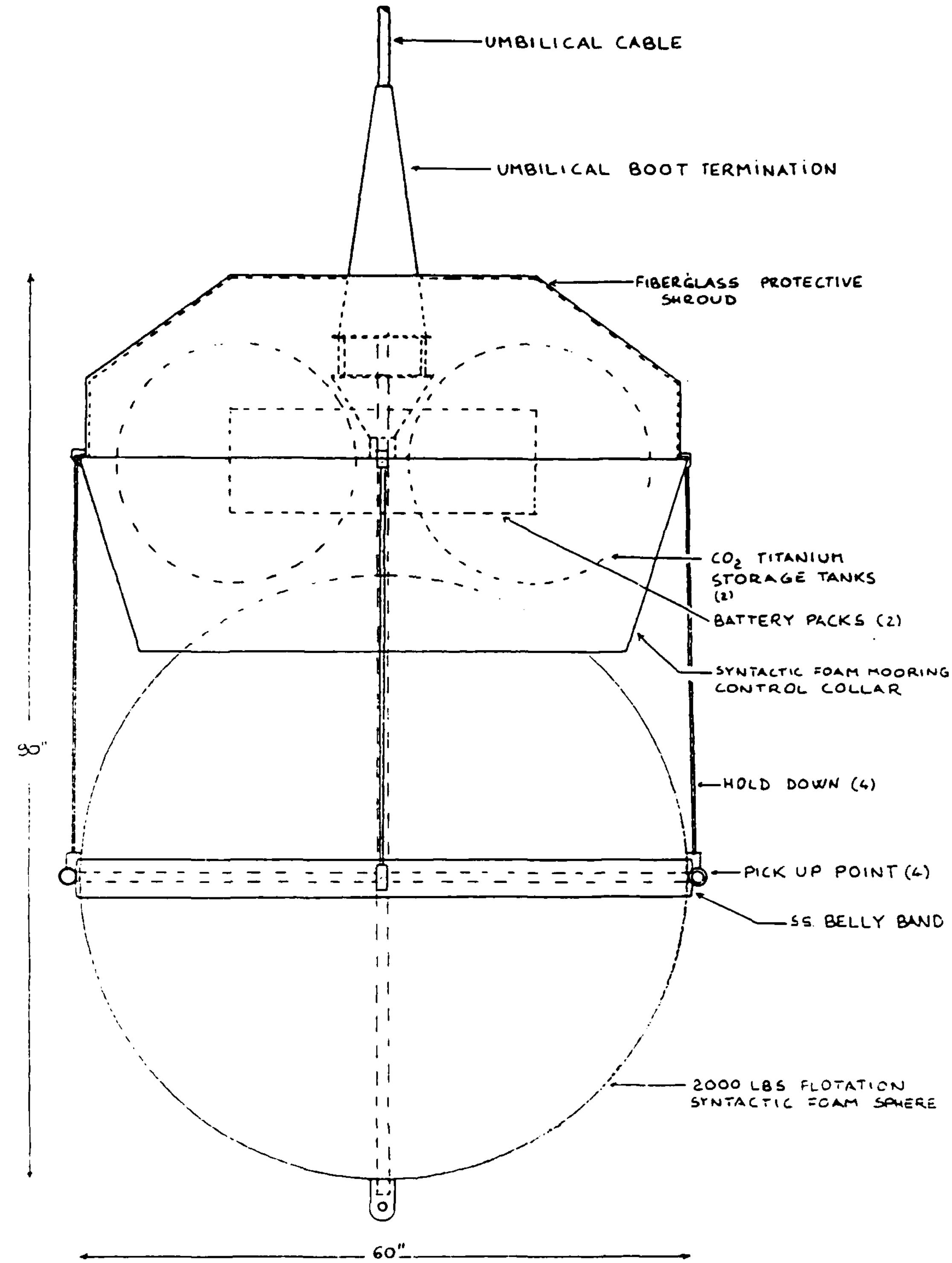

| NO | QNT. | DESCRIPTION |
|---|---|---|
| 1 | 4 | 3/4 SCHEDULE 40 PIPE - SS 316 |
| 2 | 1 | SPHERE SUPPLIED UNDER SEPARATE ORDER |
| 3 | 1 | 1 1/4 VERTICAL PIPE SCH 80 - SS 316 |
| 4 | 1 | SS 316 VERTICAL PIPE, OD = 1 9/8, ID = 1 1/2 |

Figure 12. R-TEAM Control Collar.



| [illegible] | [illegible] | DESCRIPTION | MAT'L |
|---|---|---|---|
| 1 | 4 | RINGS 8" OD - 6" ID - 3/8" THICK | SS 316 |
| 2 | 6 | HEX HEAD BOLTS 3/8" -16, 2½" LONG | " |
| 3 | 12 | NUT | " |
| 4 | 12 | FLAT WASHER AND LOCK WASHER | " |
| 5 | 2 | CIRCULAR PLATE | " |
| 6 | 1 | SPACER | " |
| 7 | 6 | TIE RODS, 3/8" - 6" LONG | " |
| 8 | 4 | GUSSETS ¼" THICK PLATE | " |
| [illegible] | 1 | BASE RING | " |
| [illegible] | 1 | ANTISPIN PLATE | " |
| [illegible] | 1 | SHIM SPACER | " |
| [illegible] | 1 | LOCKING PIN | " |
| [illegible] | 2 | DROPPED IN BUSHING | " |
| [illegible] | 1 | ROD | " |
| [illegible] | 1 | ATTACHMENT BAIL | " |
| [illegible] | 1 | ½" LOCKING BOLT W/NUT, WASHER & LOCK WASHER | |
| | | * LOCATE AND DRILL AFTER ASS'Y | |

Figure 13. Mooring Collar and 2000 lb. SSB Sphere Attachment.




AIR WEIGHT : 4,770 LBS
BUOYANCY : 2,340 LBS

**Figure 14. Buoy Assembly.**

. Electromechanical (E/M) cable

The R-TEAM E/M cable main characteristics are:

| | |
|---|---|
| Conductors: | (3) PVC insulated tinned copper AWG #20 |
| Armor: | (2) Contrahelical Galvanized Improved Plow Steel (GIPS) armors. |
| Jacket: | Pressure extruded Hytrel jacket, 0.045" wall |
| Outside diameter: | 0.478" |
| Strength: | 10,300 lbs. |
| Weight in air: | 257 lbs/1000 ft. |
| Weight in water: | 177 lbs/1000 ft. |

A cross section of the cable is shown in Figure 15. The steel armored E/M cable was built by BIW, Inc., MA, to WHOI specifications.

. E/M terminations

Special, highly reliable E/M cable terminations had to be developed, built and fully tested to terminate the R-TEAM E/M cable. These terminations had to provide full cable strength, and remain perfectly operative at depths of up to 6000 meters. A typical termination is shown in Figure 16.

Terminations and cable assemblies were made and fully tested by D.G. O'Brien (Seabrook, NH). The VMCM/hydrophone mechanical assemblies and electrical harnesses were designed and built at WHOI. The polyurethane jacketed pigtails were procured from Brantner and Associates, Inc. (CA). A typical assembly is shown in Figure 17.

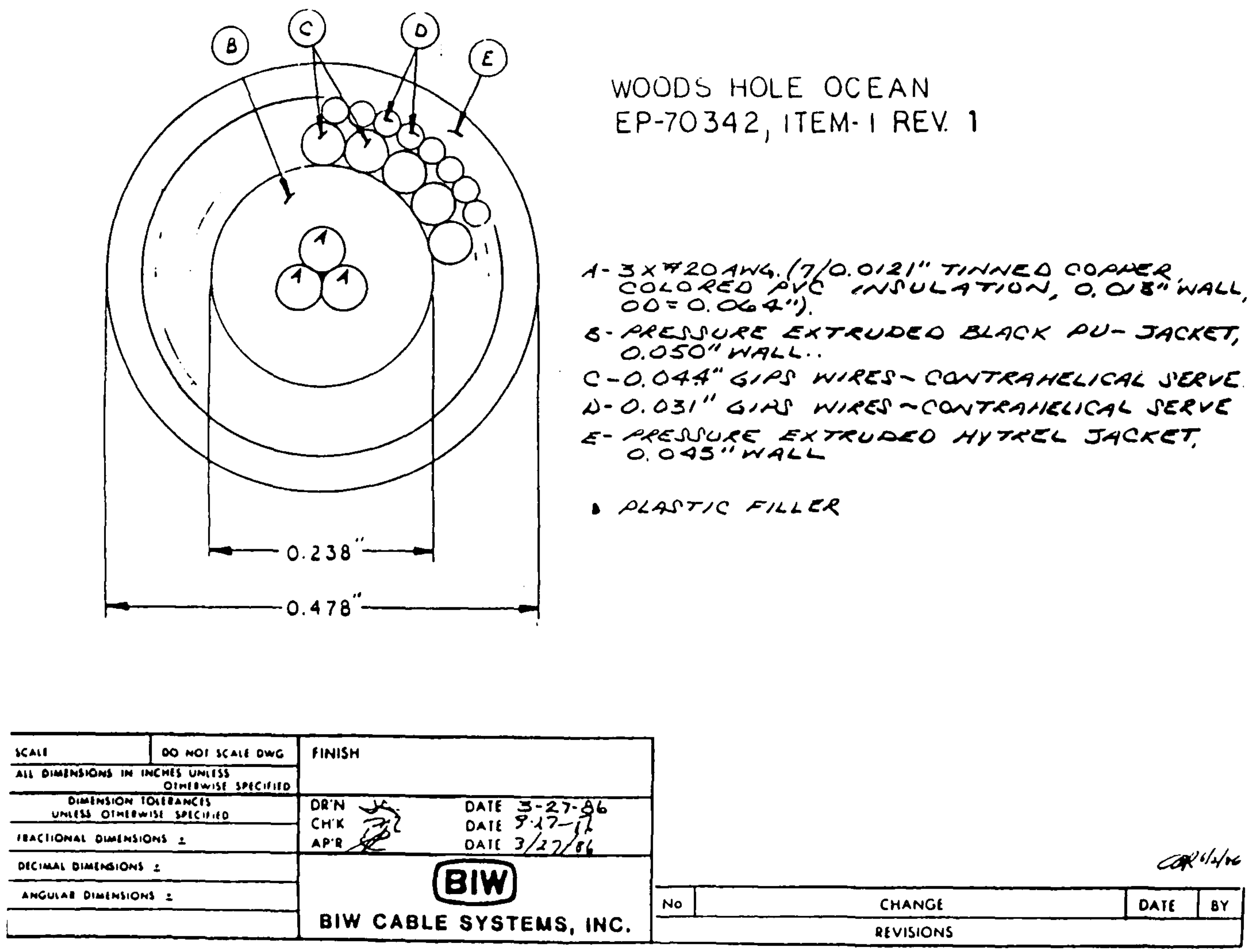



Figure 15. Steel Armored E/M Cable.

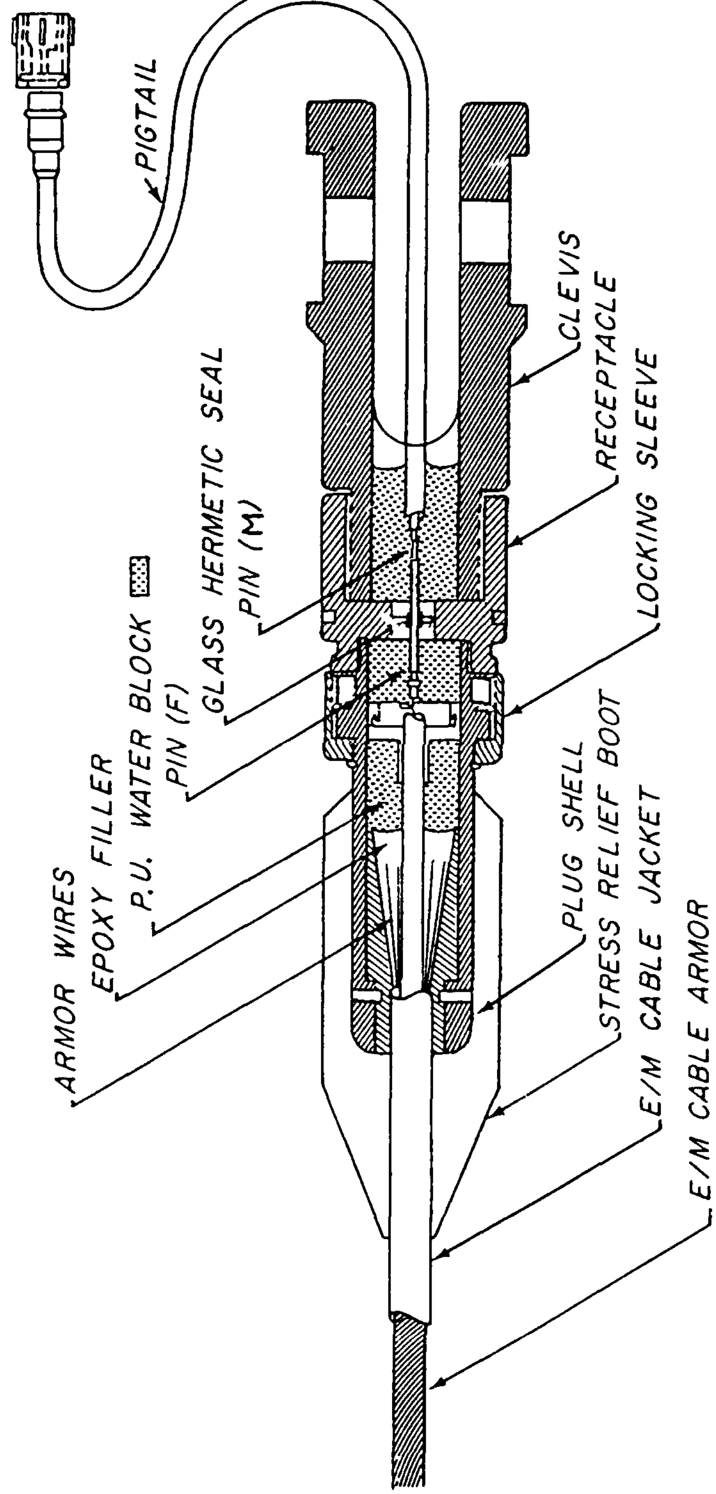
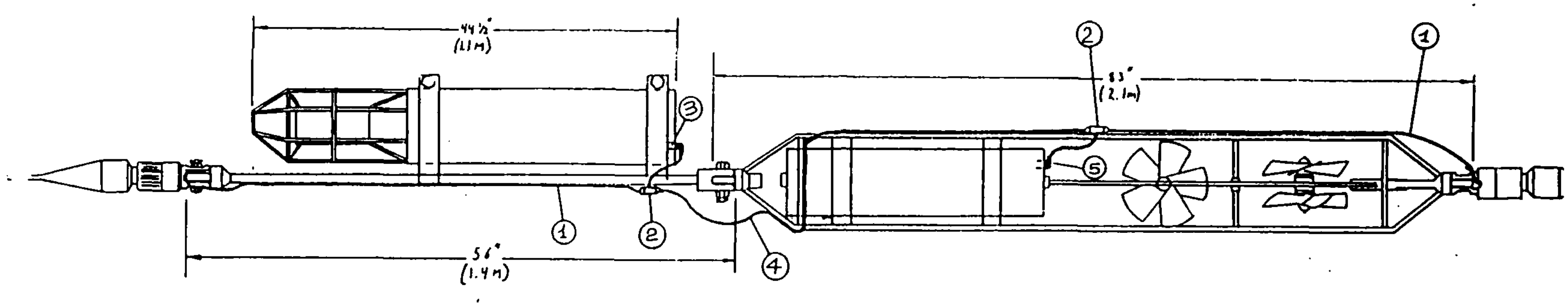



Figure 16. E/M Cable Terminations.




| | |
|---|---|
| 1 | 86" PIGTAIL-DWG # 10197209-2 REV. C; TERMINATES INTO CLEVIS |
| 2 | TEE ASSEMBLY-BRANTNER PART #6620-002 |
| 3 | BRANTNER VSG-4-BCL BULKHEAD PENETRATOR |
| 4 | 58.5" JUMPER-DWG # 10197209-3 REV. C |
| 5 | DUAL SAIL PENETRATOR; BRANTNER PART #6620-001 |
| 6 | |
| 7 | |
| | |
| | |
| | |

Figure 17. VMCM/Hydrophone Assembly.

. Wire rope

The 1/4" wire rope main features include:

| | |
|---|---|
| Construction: | 3 x 19 GIPS wires, high elastic limit, torque balanced |
| Jacket: | Extruded high density polyethylene |
| Outside diameter: | .325" |
| Strength: | 6750 lbs. |
| Weight in air: | 119 lbs/1000 ft. |
| Weight in water: | 81 lbs/1000 ft. |

The wire rope was acquired from the MacWhyte Wire Rope Company (Kenosha, WI).

. Kevlar rope

The main features of the 5/16" Kevlar rope are:

| | |
|---|---|
| Construction: | Jetstran 1-A, torque balanced, polyester center core, concentric layers of Kevlar 29, polyester jacket |
| Outside diameter: | 5/16" |
| Strength: | 9600 lbs. |
| Weight in air: | 40 lbs/1000 ft. |
| Weight in water: | 12 lbs/1000 ft. |

This rope was acquired from the Whitehill Manufacturing Company (Lima, PA).

. MF Antenna

The antenna is a standard floating antenna (P/N NUSC-C-279/1-10) covered with a nylon Zytel ST-811-HS extruded jacket of 0.045" for fishbite protection.

The MF antenna was also built by Consolidated Products, CA.

. Engineering instruments

These instruments are described in Reference 2. Each instrument, located at a critical point of the mooring, measures and records in solid state memory tension, tilt, temperature and pressure (depth). Data furnished by the engineering instruments are essential since they allow for a complete evaluation of the mooring performance upon recovery.

**4.3 Ascent Module (K. Doherty).** The ascent module prototype consists of an external fiberglass frame which contains the electronics pressure housing, submersible ARGOS antenna, MF antenna, ballast weights, and the variable buoyancy system. The overall size is 14" wide X 35" high X 85" long and weighs 410 lbs. in air. The module is ballasted at 73 lbs. negative with buoyancy tank flooded and 150 lbs. positive with the tank gas filled. An umbilical supplies electrical power, data, and high pressure gas to the ascent module. The module's general configuration is shown in Figure 18.

The ascent module is driven by a variable buoyancy system consisting of a 2.75 cu.ft. buoyancy tank, two solenoid valves and a high pressure gas source. Buoyancy is determined by the amount of gas in the buoyancy tank and is controlled by actuating the solenoid valves. To flood the buoyancy tank, the vent valve, located on top of the tank is activated allowing gas in the tank to escape and module to sink. The buoyancy tank is open at the bottom allowing a free flow of water into the tank. To blow the tank, high pressure gas is allowed to displace the water by actuating the high pressure blow valve. The pneumatic diagram is shown in Figure 19.

Initially, compressed air was used as a high pressure gas source, but after careful review, carbon dioxide $CO_2$ was chosen. $CO_2$ can be stored as a

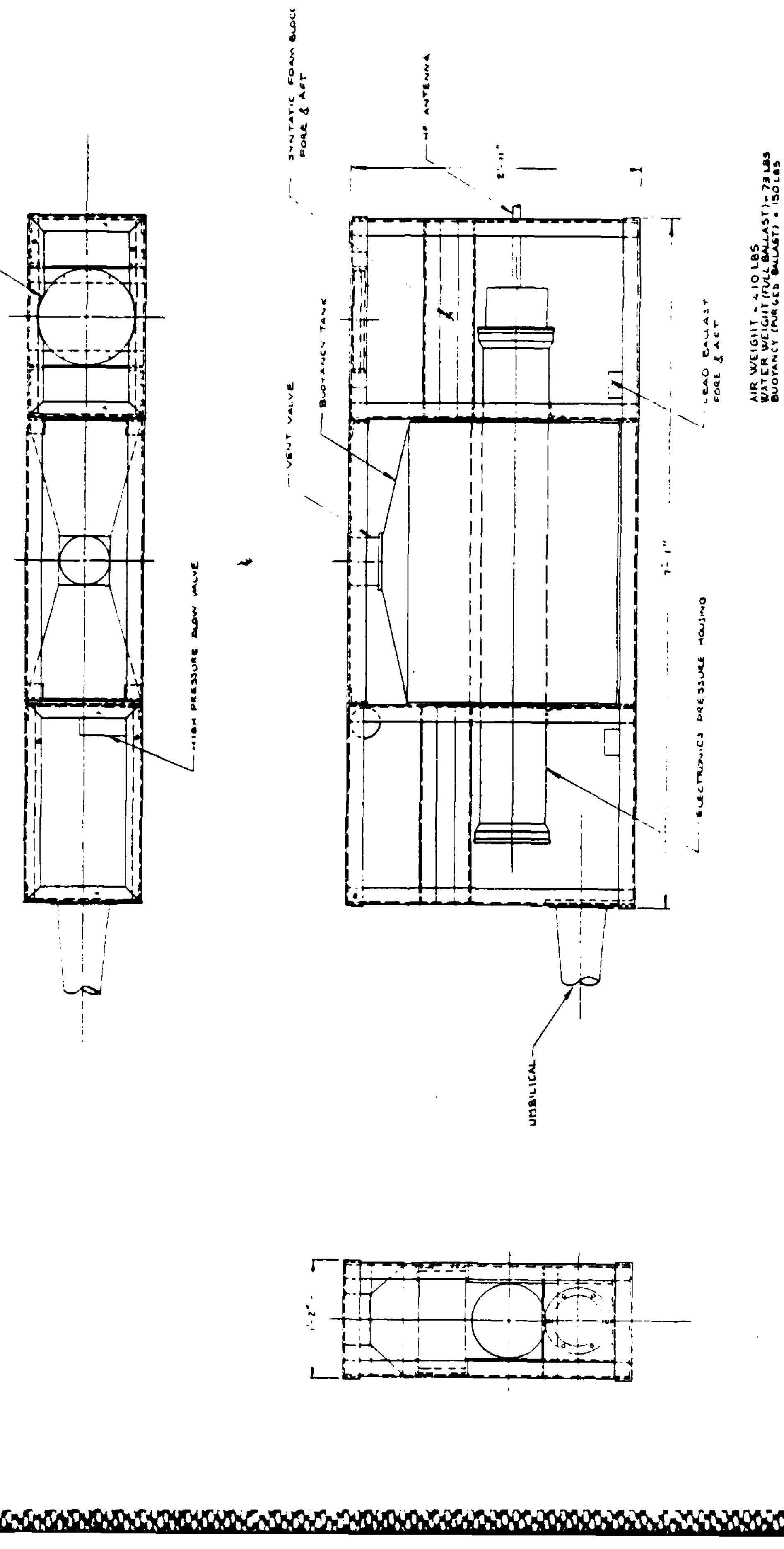
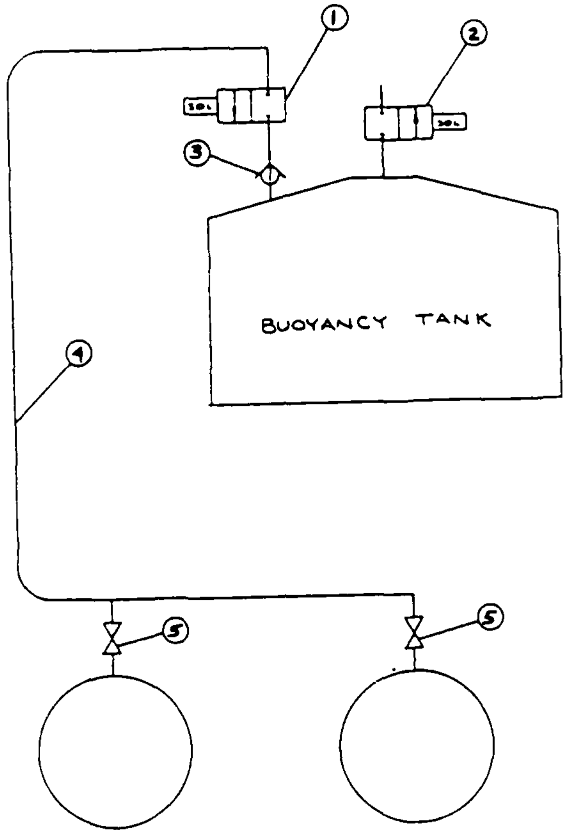



Figure 18. Ascent Module.




| | | | |
|---|---|---|---|
| 5 | SS-4P4-T | NUPRO BALL VALVE | 2 |
| 4 | 3130-05 | SYNFLEX HOSE | A/R |
| 3 | HC-4C-10 (BUNA-N) | NUPRO CHECK VALVE | 1 |
| 2 | 51C54N84-8 | VALCOR SOLENOID VALVE | 1 |
| 1 | 6610101 | KIP SOLENOID VALVE | 1 |
| ITEM | PART OR DWG. NO. | DESCRIPTION | QTY |

Figure 19. Pneumatic Diagram.

liquid at relatively low pressure, 830 psig @ 21 C, providing more available gas at a safer working pressure.

**4.4 Control and Data System (E. Mellinger).** The R-TEAM data system includes the sensors, the cable communication system, data processing computer, and MF and ARGOS transmitters. The control system, broadly defined, includes the central computer which manages and schedules all system activity, the variable buoyancy control, and the mooring power system including energy sources, distribution system, and power conversion and regulation. This section gives a summary of the implementation of each of these components, followed by an overall description of the R-TEAM system as deployed.

The prototype R-TEAM system employs two kinds of sensors: Vector Measuring Current Meters (VMCM) and Ambient Noise Hydrophone Processors. Each sensor is equipped with a SAIL/FSK modem (Reference 3), permitting it to communicate with the mooring controller over long (up to 8000m) mooring cables. The SAIL/FSK signalling system is identical to that developed and tested by the RELAYS program during 1983-1985. The mooring controller uses an Instrument Bus modem card designed for this project. The Hydrophone Processor was designed for this interface, and employs the same modem card as used by the controller. The VMCM was specifically adapted to SAIL/FSK by the addition of an intelligent pre-processor/modem card designed to fit in the VMCM card rack.

The R-TEAM system controller is an Instrument Bus 80C86 computer equipped with peripherals specific to the R-TEAM application. This computer performs all timing and control functions required in the operation of the mooring, and also functions as the central data acquisition and in-situ processing computer. In the latter role the computer acquires sensor data via SAIL at fixed time intervals, buffers the data internally, and forwards it to the transmitters during each ascent cycle. The computer has substantial processing capability for in-situ averaging and other functions. The control and scheduling functions required are managed by a real-time operating system (VRTX, from Ready Systems, Inc,) implemented for the Instrument Bus computer.

The mooring power system for R-TEAM is powered by conventional (alkaline) cells but includes several features unique to the ascent/descent and MF requirements. The gas and vent valves are driven by a high efficiency valve drive board, which allows the operating current to the valve to be reduced after the valve is actuated. By reducing the valve current by a factor of five during 99% of the valve actuation time, the valve energy budget shrinks by a factor of 25, reducing the valve energy requirement from dominant to insignificant in the overall system energy budget. The MF Transmitter battery charger is a switching regulator providing +38V out for an input range of +45V down to +20V, allowing maximum energy to be extracted from the battery pack. The low voltage +5V and +12V regular is also an advanced design capable of operation at an efficiency of 90% or greater.

The following summarizes the significant electronic development work undertaken as part of the R-TEAM project.

1. Dual Mode Power Supply. +5V at 1A / 12V at 800 mA switching regulator with 18-36V nominal input range, 90%/94% conversion efficiency, 5 mW standby power. Instrument Bus form factor.

2. Valve Driver. Dual 0-10A digitally programmable current source, 0-45V compliance range, 90% efficiency. Instrument Bus interface and form factor.

3. 7109 A/D Converter. 12 bit, 8 channel A/D converter with resistor-programmable input dividers. Instrument Bus interface and form factor.

4. Battery Charge Supply. +38V at 100 mA switching regulator with 20-45V input range. Instrument Bus form factor.

5. FSK Modem. FSK modem for SAIL/FSK (Bell 202 type, 300 baud) implemented in Instrument Bus form factor to work with existing Instrument Bus Dual Serial I/O card.

6. VRTX Multitasking Operating System. An implementation of the commercially available VRTX real-time kernel for the Instrument Bus 80C86 computer. This operating system permits a complex multi-component application such as the R-TEAM controller to be broken down into a number of individual tasks that communicate, synchronize, and perform I/O and timekeeping via operating system services.

**4.5 VMCM SAIL/FSK Modifications (J. Valdes).** The current meters utilized in the R-TEAM experiment were EG&G VMCMs. The standard instruments as available from the manufacturer measure current speed, direction, temperature, and as an available option, pressure. Engineers at EG&G working in concert with those from WHOI's Buoy Group have modified several VMCMs to measure conductivity. A standard NBIS/EG&G conductivity cell is utilized as the sensor, the specified moored system accuracy is .005 mmhos.

The VMCMs are "smart instruments", the first of a new generation of current measuring instruments which utilize the power of the microprocessor. They are available with a SAIL (Serial ASCII Instrumentation Loop) option which permits two way communication with the instrument using a half-duplex 20 ma. loop. Details of the SAIL protocol may be found in the IEEE standards, number IEE 997. As designed into the instrument the SAIL port is intended primarily as a diagnostic tool, it exercises several go /no go tests and upon command will output the record data buffer. It is not intended to be used after the instrument are deployed. However, it is possible to communicate with the instrument underwater through the 20 ma. loop provided suitable underwater connectors are used. The 20 ma. current loop limits the practicality of such a system to a few tens of meters, and places stringent demands on the remote power source.

In this experiment an additional circuit card, an FSK pre-processor module, was added to a standard VMCM to implement the SAIL/FSK protocol. The intent was to make FSK communications transparent to the host instrument. In the FSK application only minor changes were required. One circuit board was added, the external SAIL connector was replaced and six jumpers were made on the backplane to route the data to the appropriate points. The FSK data is electronically "ORed" to the UART on the serial interface board, preserving the normal 20 ma. SAIL capabilities of the instrument.

The SAIL/FSK pre-processor module is comprised of the FSK data modem developed for the RELAYS system by Mellinger, et al. and an additional microprocessor which monitors the transactions taking place on the FSK line and regenerates to the VMCM via the logic lines the address when detected. This minimizes the impact on the current meter. The pre-processor also implements the necessary changes to the SAIL protocol to make it compatible with the FSK transmission. Complete documentation on the FSK pre-processor circuitry and instrument modifications will be found in a WHOI Technical Report currently in preparation (Reference 4).

**4.6 Telemetry Development (J. Hager).** This section describes the work performed to date by DSI on the communications portion of the R-TEAM project. Phase 1 commenced in April 1986 and was a study of communication methods from under ice and the development of hardware to implement the chosen scheme. Phase 2 commenced in February 1987 and provided for the fabrication of final hardware, integration into the buoy, and testing.

**Phase 1.** The initial thrust of the DSI proposal was to utilize direct ARGOS telemetry for open water, and, when ice covered, HF to an above the ice repeater for ARGOS. The repeater would be air-dropped and replaced when it drifted out of range of the buoy. To simplify the ice-over scenario, DSI restudied through the ice VHF propagation literature and devised several antenna alternatives for under-ice use. Relevant measurements taken at 173 MHz by Kennedy in MIZEX 84 (Reference 5) show 4-5 dB attenuation per meter of ice, which would be the equivalent of 6-8 dB/meter at 400 MHz. Kennedy also showed that the variation in attenuation is a function of ice conductivity and is quite variable between old and new ice. The high attenuation of the 400 MHz signal (40 dB plus or minus) for several meters of ice caused the direct VHF link to be discarded.

Additional work done by Kennedy in MIZEX 84 examined propagation of MF and HF waves through ice and in a surface wave mode over sea water. He concluded that ice is relatively transparent to MF waves and begins to show significant attenuation above 2 MHz. Based on the results of this work, DSI showed that a long haul MF telemetry system would be feasible from below the ice given that sufficient energy could be radiated. This led to the floating wire antenna concept as used by the Navy for some submarine communications.

In order to characterize a floating wire antenna and determine required transmitter characteristics, DSI devised a tow-along buoy with test fixtures inside; this allowed impedance measurements on a 200' lengths of floating wire. This assembly was tested in the Chesapeake Bay and impedance vs. frequency for power transmitter was built for the buoy which could drive the antenna at either its open or shorted end impedance at 500 KHz. This assembly was taken aboard the WHOI R/V ASTERIAS in July 1986 and floated between Marthas Vineyard and Block Island with a calibrated receiver and antenna on Gay Head, Marthas Vineyard. Transmissions and received signal power were measured as a function of distance, orientation of the antenna, and versus open or shorted antenna. These data are included in Appendix A. The shorted antenna gave the highest radiated signal level and was selected for the system.

From the results of the antenna test, an antenna factor, the gain of the antenna relative to an isotropic antenna, was derived. With this antenna factor, it was shown that a 150 to 200 nautical miles MF link was achievable with about 100 watts of transmitter power, using BPSK modulation, a 75 Bps data rate, and 250 Hz receive bandwidth. Thus the under-ice link was committed to this mode of transmission to a fixed shore-mounted repeater to ARGOS.

The balance of communications electronics was designed and breadboarded during Phase 1. These included the MF modulator, power amplifier, battery, power conditioner and charger, communications processor, and comms processor software.

Based on the antenna impedance measurements, it was desirable to have a 400' resonant antenna for ease of matching to the MF transmitter. WHOI pointed out several operational problems with such a long wire and a 100' element was agreed upon as the best physical and electrical compromise. The MF transmitter and matching network were then modified for the projected impedance (resistance plus reactance) of a 100' line.

**Phase 2.** WHOI procured floating wire antenna material with a Zytel coating to be more resistant to fishbite. Samples of this cable were potted to both end fittings by DSI and pressure tested by WHOI. Each end fitting was then carefully dissected to check for leaks and potting adhesion. In both cases the potting appeared normal and no leaking occurred. The cable was cut to 100' and terminated with a brass fitting to short the end to the sea water. DSI then performed three tests in the Chesapeake Bay to characterize the final version antenna for pattern, antenna factor, and impedance. The data from these tests is in Appendix A.

All final buoy hardware and software was produced during this phase. Final assembly of the communications portion at DSI was followed by integration with the WHOI assemblies at WHOI.

The MF receiving site was also developed at this time and was designed for autonomous operation in Bermuda for the 4 month scheduled test. This set has not been used because that portion of the tests was cancelled and replaced by a deployment at Site D.

As a result of sea water contamination at the beginning of the Bermuda test, the communications portion of the buoy was refabricated using existing spare boards and retested at DSI and WHOI prior to the deployment at Site "D".

## 5. BUOY SYSTEM TESTS (P. Clay).

**5.1 Components Testing.** All system components were tested prior to both their integration in subsystems and their deployment at sea.

. Syntactic foam: Companion samples from the two subsurface buoys, the mooring collar and the umbilical floats were subjected to a Shore D hardness test and to a 24 hour pressure test (2750 psi) in order to insure proper foam curing and determine water absorption rate. Test results are shown in Table 5.

**Table 5**
**Syntactic Foam Acceptance Test**

| Tested Material | Average Density | Average Water Absorption |
|---|---|---|
| Umbilical floats | 32.0 lbs/cu.ft | 2.08% (of total dry wgt) |
| Mooring collar | 36.04 " | 1.0% " " " " |
| 2000 lb. sphere | 36.46 " | 1.52% " " " " |
| 1000 lb. sphere (from HIPOM) | 40.0 " | 2.0% " " " " |

. MF Antenna: A sample of the MF antenna was terminated by DSI with a polyurethane boot and pressure tested at WHOI for 24 hours at 500 psi. No water leaks were found. Subsequently a tension test showed a satisfactory bond between the polyurethane boot/termination and the antenna Zytel jacket.

. Umbilical cable: Prior to acceptance, the cable was tested for electrical continuity of the conductors and air-tightness of the air hose core. An umbilical sample was potted with polyurethane and pressure tested to verify the feasibility and strength of the R-TEAM boot termination (Figure 20). A length of umbilical cable (4') was pull tested to destruction in the WHOI tensile machine. The sample broke at 2800 lbs. and signal continuity was maintained up to the breaking point.

. Battery pressure cases: These pressure cases (Figure 11) were tested for leak tightness and integrity in the large pressure vessel of the WHOI Pressure Test Facility. They were held at twice their anticipated deployment depth (150 meters) for 24 hours without any detectable leaks or damage.

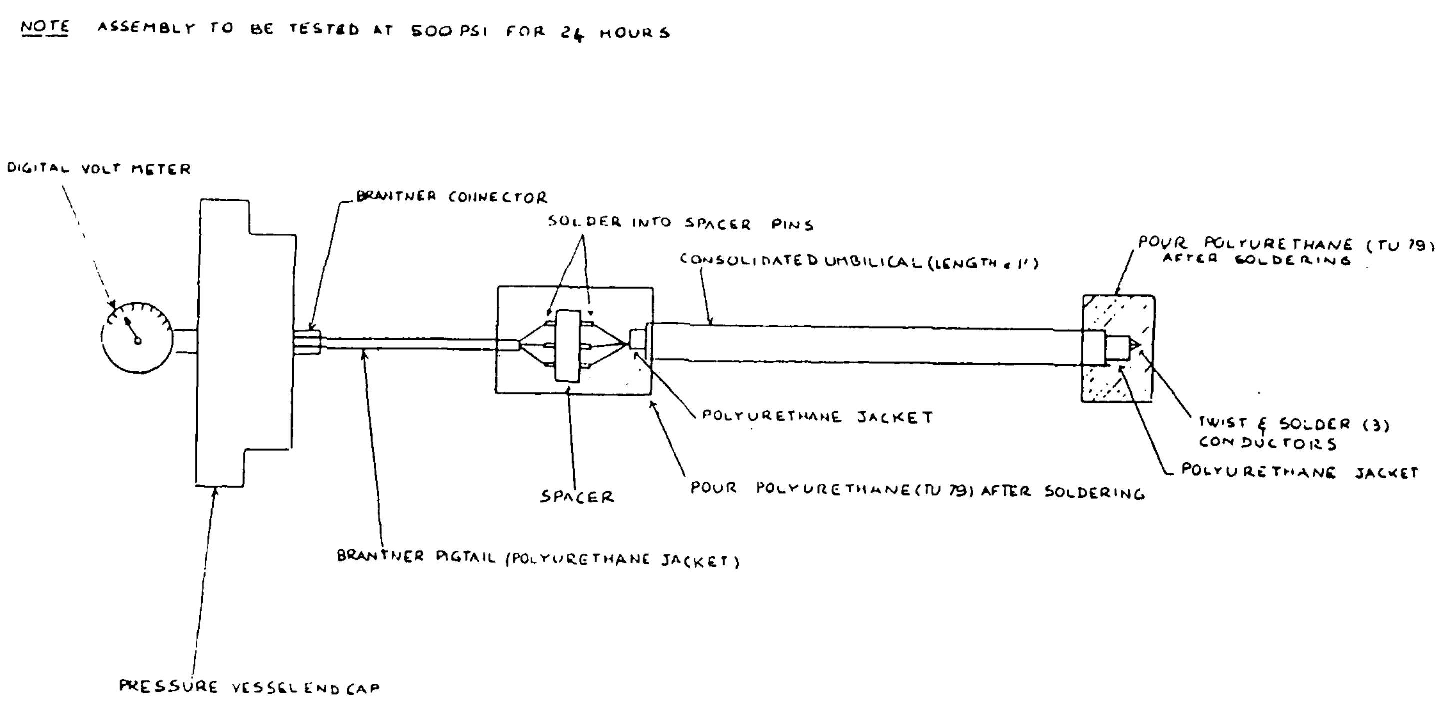



Figure 20. Continuity Test for Umbilical Boot/Termination.

. Titanium gas storage tanks: Both tanks were pressure tested at the WHOI facility under the supervision of A. Sharp (Alvin Group). The spheres were filled with water and pressurized at 4500 psi for two cycles of 5 minutes each. The actual $CO_2$ pressure to be used at sea is 750 psia at $60^{o}F$.

. Electromechanical terminations: All electromechanical assemblies (clevis, cable to cable, straight plug), built and designed by D.G. O'Brien in collaboration with the OS&M Lab, were tested for continuity under tension (6000 lbs.), continuity up to break (7890 lbs.), and for water tight integrity up to a pressure of 10,000 psi for 24 hours. As a result of the handling and testing done at WHOI the following changes were introduced in the original design.

1. Different epoxy to prevent torquing of the epoxy/urethane within the fitting back shell.
2. Inspection port to insure O-ring complete compression (use of a go/no-go gauge will insure the same).
3. Set screw lock arrangement instead of the seizing wire.
4. Make all spanner holes the same size.
5. Add spanner holes to bulkhead connectors to prevent turning.
6. Nylock insert on the nut of bulkhead connector to prevent backing off while disassembling cables.
7. Use new boot (urethane) primer technique on Hytrel cable jacket.

. E/M Cable assemblies: When completed each assembly was pressure tested at the Portsmouth Naval Shipyard. Whole assemblies mounted on reels were placed in the pressure vessel and pressurized for 4 hours at 2800-3000 psig. No shorts or continuity breaks were found.

. Buoy assembly lifting test: The 2000 lb. SSB sphere with belly band, the control collar, and a 4100 lb. clump anchor were lifted with the 4 lifting points of the belly band. The static load was 7200 lbs. and the jerk load 8000 lbs. No yield or failure was observed in the lifting bails.

. Wire rope and Kevlar rope tests and measurements: Rope samples were tested to determine their stretch, spin and breaking strength characteristics. The critical position of the top SSB sphere requires an exact measurement of all mooring components when subjected to the tension level they will experience after deployment. To this end all mooring assemblies where laser measured under computer predicted tension at the Bedford Airfield (MA). The results are shown in Table 6.

**Table 6**
**Laser Length Measurement**

| *Unstretched* length (m) | *Breaking* Strength (lbs) | 200 lbs. laser measurement | *Tension* loaded to lbs. | Stretched length (m) | Remarks |
|---|---|---|---|---|---|
| 96 E/M cable | 10300 | -------- | 2182 | 97.724 | clevis - clevis |
| 296 E/M cable | " | 296.376 | 1883 | 298.116 | " " |
| 492 E/M cable | " | 492.221 | 1520 | 494.380 | " " |
| 474 1/4" Wire Rope | 6750 | 474.423 | 2000 | 476.151 | eye - eye |
| 500 1/4" Wire Rope | " | 500.046 | 2000 | 501.926 | " " |
| 400 5/16" Kevlar | 9600 | 400.954 | 2400 | 404.003 | " " |
| 400 5/16" Kevlar | " | 400.878 | 2400 | 404.003 | " " |
| 495 5/16" Kevlar | " | 496.108 | 1920 | 499.169 | " " |

**5.2 Ascent Module Test.** In order to gain information about the dynamics of the buoyancy tether cable and the variable ballast elevator module a shallow water prototype mooring was built. This mooring was to be tested in an area with both high speed and reversing direction currents thereby forcing the buoyant tether to rotate or swing in opposite directions. Two main concerns were addressed: 1) The feasibility of the variable ballast concept using compressed air as a purge gas and, 2) The ability of the buoyant tether cable to respond to current direction changes without tangling. The test mooring included 3 components:

a) Anchor module with 4 air diving tanks used to displace water in the variable ballast chamber of the ascent module.

b) Hard polyethylene buoyant tether with 3 conductors and a nylon air hose strapped on the outside jacket.

c) Elevator module with a Tattle Tale computer to regulate the hourly ascent and descent cycle and a VHF radio (170 Mhz) to confirm surfacing to a listening shore station (24 cycles a day).

Prior to final deployment at sea, the prototype was tested several times from the WHOI dock to determine the correct amount of air needed for surfacing, the rest position and orientation of module and umbilical (with help of divers).

The prototype mooring together with a current monitoring mooring (Figure 21) were finally deployed on February 2, 1987 at Job's Neck, an area very close to WHOI with suitable current and depth. The duration of the test was 2 weeks. The S4 current meters collected data which were subsequently used to study the dynamics of the elevator mooring.

The test results were excellent, no problems were reported with the mooring or the elevator buoy and the general concept seemed to work very well. Data on the rest position of the elevator module are illustrated in Figure 22. When the current was over 2.5 knots the elevator module came close, but did not reach the surface due to the higher drag.

**5.3 Precruise Tests.** $CO_2$ gas was adopted as purge gas for the variable ballast system (see Section 4.3). In order to gain a better knowledge of the gas dissolubility rate when in contact with seawater, the

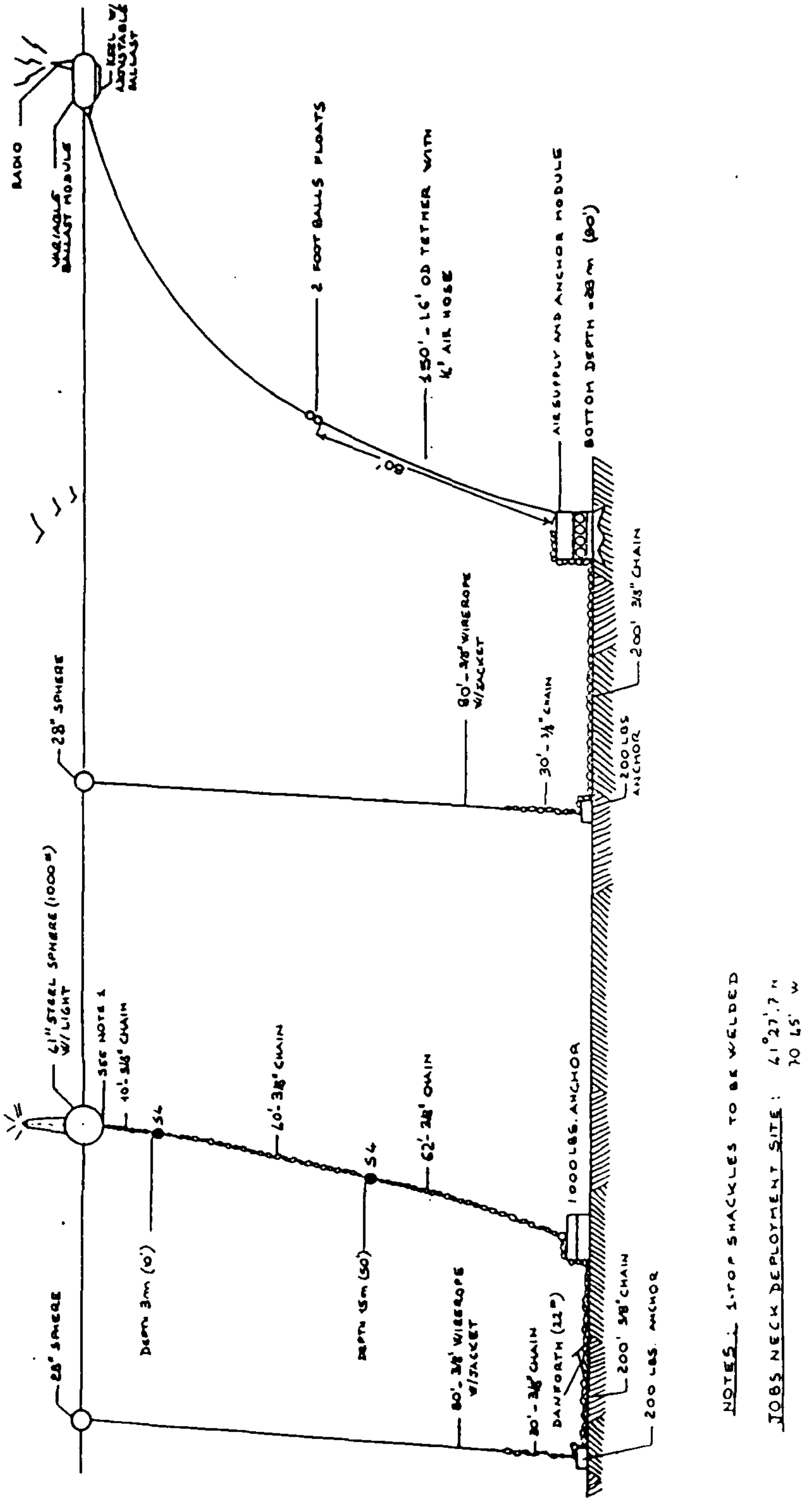



Figure 21. Ascent Module Test.

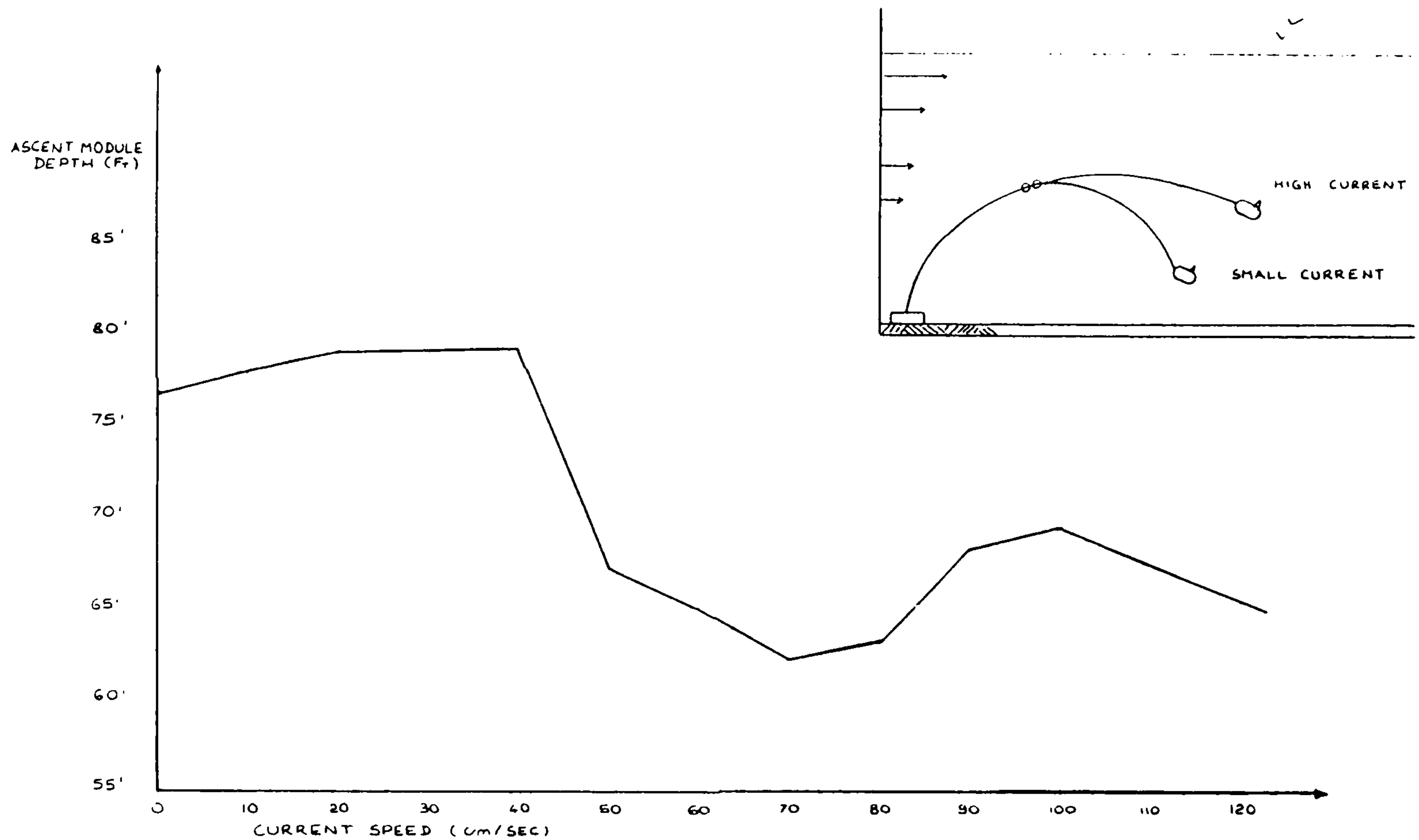



Figure 22. Ascent Module Test. Rest Position as a Function of Current.

ascent module, with the variable ballast chamber filled of $CO_2$, was anchored for 24 hours on the sea bottom (60 ft.) at the end of the WHOI pier. Loss of gas was minimal. Numerous ascent and descent cycles where then performed to determine purge and fill time, ascent rate, rest position and umbilical trajectory (with divers). More bench tests were conducted on valves, connections, and piping in order to minimize gas leaks which could affect the duration of the prototype test.

Before sea departure, the VMCMs and hydrophone were connected together with the predetermined E/M cable lengths. A TRS 80 model 100 portable computer was used to interrogate the sensors through the cable assemblies to check communication links. Proper reply was received from each sensor. Finally, the sensors were interrogated by the controller and data was sent to the ARGOS transmitter to check the satellite link. All transmission results were satisfactory.

### 5.4 R-TEAM Prototype Deep Sea Test.

**5.4.1 Deployment.** The initial plan to deploy the R-TEAM mooring from the R/V OCEANUS (Cruise #187) in the vicinity of Bermuda was cancelled due to early electronic component failure detected on board the ship. The ship returned to WHOI to allow for repair of the controller/transmitter unit. Deployment site was changed to Site D and the mooring was successfully deployed on 2 June 1987 at location $39^{o}10.7$'N and $70^{o}06.1$'W. Water depth was 2687m.

Prior to deployment, the ascent module was run through a test cycle while tethered to the ship. This was to test both MF and ARGOS transmission, proper ascent and descent sequencing, and to practice deploying the ascent module and umbilical assembly.

Although the mechanical aspects were successful, MF transmission were not received, am attempt at correcting the problem (blown MF transistor) was unsuccessful due to lack of parts and time. However, the 100 ft. antenna was left on for mechanical endurance testing.

Mooring deployment began at 1745 with the 100' antenna and ended at 2205L with the anchor going over. A 50m shot of 1/4" wire rope was added to the mooring to account for the 48m discrepancy between design and actual depth. Final mooring position was boxed in acoustically at $39^{\circ}10.7'$N and $70^{\circ}06.1'$W using the Northstar 7000 Loran. Anchor fallback was calculated to be about 21%. At each instrument insertion the SAIL interface loop integrity was checked through to all instruments, with successful acquisition being achieved at all locations. Load transferring from all instruments was done using Yale grips which worked very well. All E/M cable connectors were carefully assembled with O-rings, spanner wrenches and set screws, and stopped off with Yale grip soft eyes.

The deployment of the sphere and collar module (Figure 14) went smoothly, having been well tested at the dock prior to sailing. Having the sphere stored horizontally along the starboard rail (Figure 23) proved to be very convenient. Once the umbilical was payed out and transferred over to the sphere, the sphere could be lifted horizontally with its sling and deployed over the side. Once in the water and released, the sphere moved slowly to the stern as we lowered the top VMCM down with the A-frame outrigger. When the strain came on the VMCM we were able to quickly lower the instrument and the 97m E/M cable below it. Shock loads, due to the dynamics of ship motion, were greatly decreased using this procedure.

Three winches were used in the launch. The umbilical was stored and launched from a large wooden RELAYS reel on the large Reel-o-matic. All E/M

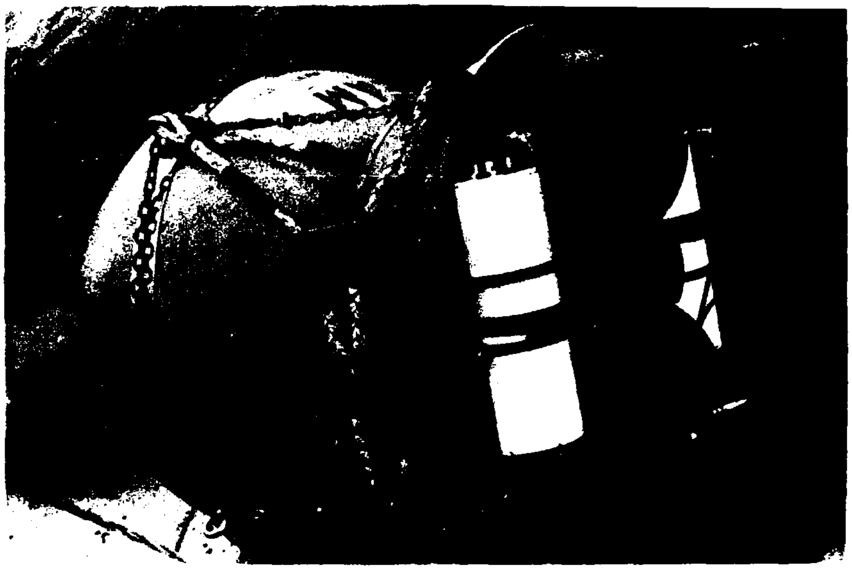


Figure 23. SSB Sphere and Mooring Collar Assembly.

cable sections were deployed from individual aluminum reels on the gasoline winch and all standard mechanical sections were deployed from the diesel Pengo winch. All new cable and antenna lengths handled very well and payed out evenly. Some spiralling of the umbilical on the surface was evident until enough strain pulled the spirals out permanently.

Following deployment, the module was programmed to remain on the surface until first light the next morning. Prior to the first descent, ARGOS transmitted data was received, including current meter data, however, no additional transmissions were heard after descent. Ascent and descent cycles worked beautifully, and having a polyform float on the surface helped to locate the module and gave a good reference point during module ascents. An attempt was made from the Zodiac to check both the mechanical components of the module and access the computer using a Radio Shack model 100 portable terminal. Mechanically things looked good, but access to the computer was unsuccessful due to incompatible baud rates between computer and terminal.

The following day, after the weather had improved somewhat, we recovered the ascent module only long enough to remove the MF and ARGOS antennas and the electronics, leaving the pressure housing open to sea water. When the module came aboard, it was stripped in about 10 minutes, while the umbilical was hand held, paying in or out as necessary. Excellent ship handling allowed us to do this without putting any strain on the mooring below. After removing all the intended pieces, we reversed the process, slowly paying out as the ship drifted away from the mooring.

Upon inspection of the electronics, it was found that a flooded Brantner bulkhead connector cap had caused shorting, resulting in drained batteries, burned out wires and no data transmissions. To correct this, the wires going to the test bulkhead connector were cut and the faulty cap and bulkhead connector were filed and sanded until proper o-ring seating was obtained.

The electronics were reassembled in the ascent module after again recovering it over the stern. When aboard, all four current meters and the hydrophone were interrogated through the computer and down the mooring string. Once redeployed, we again received ARGOS transmissions with current meter data, however, after the first descent we received only engineering data. The hourly cycling worked as scheduled, then switched directly to a twice per day cycle which was around 0400 and 0900 each day.

On 5 June 1987, just prior to leaving Site D, we recovered the polyform float and polypro with the Zodiac when the module came up for its scheduled transmission at 0900. The OCEANUS arrived at the Woods Hole dock around 0630 on Saturday, 6 June 1987.

Engineering data gathered by the ascent module (main battery voltage, temperature internal and external pressure, transmitters current) were received at WHOI through ARGOS satellite link from June 2th to July 11th, 1987. A tabulation of these data is shown in Appendix C. The ambient pressure of the elevator module in the rest position thus obtained is shown in Figure 24.

No current meter data, however, were received during the active telemetry time span.

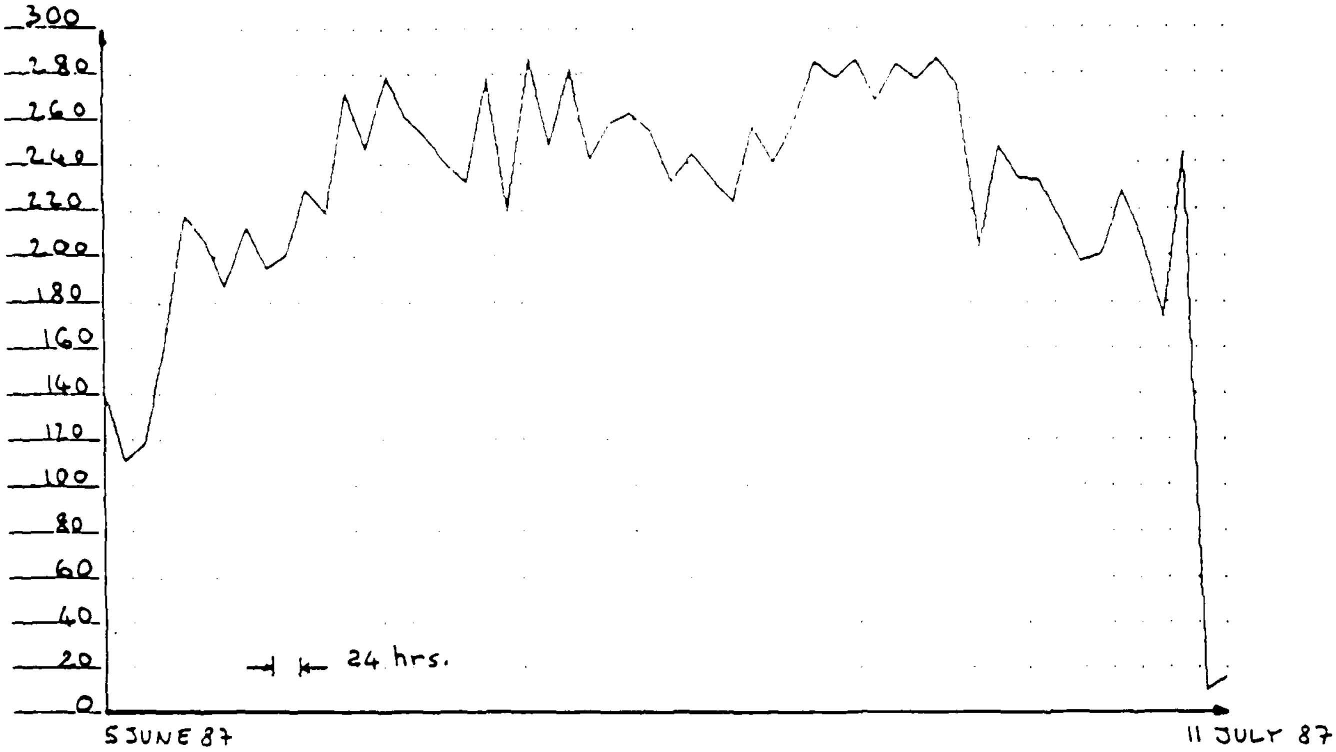



**Figure 24. Elevator Module Ambient Pressure in Rest Position.**

**5.4.2 Recovery.** The R-TEAM mooring was recovered smoothly on August 3, 1987 from the R/V OCEANUS on cruise #191-2. Time allotted for the recovery was only 6-8 hours. This, combined with an unfavorable weather forecast, impelled us to recover the mooring without delay. The next scheduled ascent time was 3.5 hours away, so we elected to fire the release and proceed with the recovery.

First release interrogation took place at 0535L. When proper ranging was completed and the slant ranges began to increase, the release commands were sent at 0550L. The large sphere surfaced three minutes later (0553L) about 300 yards astern. We waited for the backup flotation to surface and at 0615L began our approach to the bottom end of the mooring. The wind was out of the South at 10-12 knots, sea state was 3-4, and swell 1.

Recovery commenced at 0645L with the glass balls and releases coming aboard first. With the mooring laying across the wind and seas, we steamed slowly in a large arc until the ship was headed into the wind. This strung the upper part of the mooring out behind us and gave the ship both better control and less motion than if we had layed-to in the trough. Normal recovery techniques continued until we reached the 1000 lb. sphere. This was lifted using the TSE winch with the 1/4 in. wire. The air tuggers on either side were attached using pickup poles and the sphere came aboard smoothly and was placed in its stand. After moving the 1000 lb. sphere out of the way and recovering the bottom VMCM and first E/M cable termination, we stopped off and connected to a terminal in the main lab.

Access to the other 3 current meters and the hydrophone through the 492, 296 and 96m E/M cables was successful via the FSK/SAIL loop. Accessing the bottom VMCM was also successful by plugging in directly with the cable to the terminal. Stopping off at each current meter was achieved by using the Yale grips previously placed on the cables near the terminations. Once stopped off, the D.G. O'Brien terminations were dissembled, watertight caps or plugs attached and the Yale grip eyes shackled together. The loose cable lengths beyond the Yale grips were taped to the respective standing parts of the cables and the assemblies wound on to the winch after carefully covering the connectors with canvas. This procedure continued for the rest of the VMCMs.

Once stopped off at the top VMCM the rubber boat was launched to attach the trawl wire and frapping lines to the large sphere, now 23 meters astern of the ship. The trawl wire was led through a short block on the A-frame and the tuggers' frapping lines through the stern chocks both port and starboard. The E/M cable leading to the bottom of the sphere from the winch remained attached and was used to pull the sphere forward. Once the rubber boat was back aboard, the trawl wire took the strain and we increased our speed through the water to about 2 knots. This additional drag astern helped the sphere clear the stern as we two-blocked the sphere's lifting sling and then boomed in on the A-frame, sliding the sphere over the rail. Side loading by the tuggers prevented rolling and once clear of the stern the TSE winch was able to provide a forward strain so that very little sphere motion was experienced. Once in its stand between the A-frame, block and tackles were rigged to move the sphere forward out of the way.

Once the sphere was in its stored position and lashed down, we continued recovery by attaching Yale grips to the umbilical which was streaming aft, after the fiberglass housing over the batteries and titanium spheres had been removed. Sphere $CO_2$ valves were shut off and electrical and plumbing fittings to the umbilical cable were removed. The umbilical boot was then removed and the load was slipped to the RELAYS winch. While still steaming forward we wound the umbilical cable, cutting off the syntactic floats at 40m. The ascent module and the 100 ft. MF antenna with its parachute came aboard at 1053L. The umbilical cable and ascent module were recovered on the starboard side of the A-frame using the A-frame outrigger.

Shortly after recovery further electrical tests were made by talking to a VMCM through the top 23m shot of E/M cable, sphere pigtail and battery housing, and through the umbilical cable. We were not able to check power or power continuity, but will do so upon return to Woods Hole. These tests, however, did prove that electrical signals were obtainable from the ascent module down to the bottom VMCM at 1000m. This included the badly damaged

23m top E/M cable. Dynamics while attaching the trawl wire to the sphere and subsequently contact with the ship and $90^{o}$ bending loads, destroyed sections of the cable jacket and mechanically damaged the strength members.

From a normal mooring recovery standpoint, this mooring exhibited exceptionally untangled characteristics. There were no tangled sections, including the 100 ft. antenna with its little drag chute which was streaming perfectly when recovered. No fishbite evidence was found and the only jacket damage found was that which we made at the rail during the recovery.

Fouling above 75m after long periods of time at these latitudes could possibly present a problem unless precautions were made in advance. Slime and some goose neck barnacles were found on the umbilical cable and the syntactic collar floats. In the Arctic this should not be a problem.

Additional corrosion protection should be provided in the ascent module. Aluminum oxidation was evident around the pressure housing near the rear end cap and where stainless steel tubing connects with aluminum. Proper electrical protection through adequate zinc placement should improve the situation.

The only failure observed in a mechanical component was the small bladder on the stainless steel valve assembly on the upper forward section of the ascent module. This is believed to be the problem which caused the module to not ascend properly.

After recovery ARGOS transmissions were received back at Woods Hole on the scheduled transmission at 0255L on 4 August 1987. This implies that electrically the system was still working properly and within its timing tolerances. Battery voltages were still up at around 45 volts and the $CO_2$ spheres and umbilical cable were still charged at recovery.

Two days after recovery a good vacuum was still present in the ascent module electronics pressure housing. These were the last tests performed at sea prior to arriving at Woods Hole.

Personnel transfer to the R/V SEWARD JOHNSON was made at 0900 on 9 August 1987 and the ship arrived in Woods Hole at 1830 that evening. The R/V OCEANUS returned to Woods Hole with the gear and equipment on 17 August 1987.

**5.4.3 Results.** On the positive side, the prototype deployment was very instructive and successful. It demonstrated concept feasibility, and confirmed the soundness of the design with the ascent module ascending 80 times in 40 days. The ascent schedule was computer controlled and synchronous with the passage of ARGOS satellites above Site D. The umbilical length, combined with a very precise implantation of the subsurface top sphere permitted the module to reach the surface every time. All components were recovered in good to excellent shape, with no signs of abuse or deterioration. Pressure data received indicated that the ascent module was resting at its anticipated depth, well below the surface (Appendix B). On the negative side, the test revealed two deficiencies which need to be fully assessed and fully corrected. The first is an interruption of the ascent cycling after 40 days. The second is a lack of current meter telemetry during the whole deployment time.

Inspection of the R-TEAM ascent module revealed a ruptured oil compensating diaphragm. Leakage of $CO_2$ gas into the oil filled solenoid valve housing had ruptured the diaphragm causing oil to escape and sea water to enter. The seawater eventually found its way to the bulkhead connector terminals, supplying power to the solenoid, corroding and open circuiting them. In the process, fuses were blown in each of the systems battery power supplies, cutting power to the R-TEAM ascent module.

A visual inspection of the valve O-ring, that seals $CO_2$ gas from the oil, revealed many radial cracks causing the seal to fail. Engineers from Parker Seal Company believe that the failure was due to a combination of low temperature and explosive decompression. They recommended another seal compound that is especially formulated for this situation. New O-ring specifications will include this suggested seal formulation.

It may also prove advantageous to add a relief valve to the oil filled housing to vent off pressure due to any escaping gas and thus prevent the diaphragm from rupturing.

We will also consider putting the valve in a pressure vessel. This vessel would confine the pressure of escaping $CO_2$ gas and allow the valve to operate with a failed seal.

The cause of the telemetry failure was hard to pinpoint. It seems that the communication link between the controller in the ascent module and the sensors on the line, which functioned perfectly before, during, and immediately after deployment, failed soon thereafter with the result that little sensor data was telemetered during the test. Upon recovery, the controller and the communication link again functioned correctly, and as of this writing it continues to do so while cycling in a test mode on the WHOI dock. The cause of the failure is at this time unknown; possible causes which will be investigated further include intermittent electronic component failure, intermittent connector contact, or a well-hidden software bug in the controller. Since nearly identical communication technology has been employed without incident since 1984 (RELAYS program), it is not expected that major redesign will be required to correct this problem.

## 6. FUTURE WORK (H.O. Berteaux).

The operational R-TEAM mooring will be deployed in early September, 1988. Site selection will depend on the MF "through the ice" link range, water depth and ice conditions. A shore based radio station will receive the MF data and relay the data to ARGOS satellites as needed. The following tasks remain to be done to deploy the mooring as anticipated: Site D data analysis, correlate mooring/ascent module geometry versus currents and check against computer predictions, determine rate of ascent, speed of ascent, speed at surfacing, determine gas consumption rate, power consumption, and assessment and correction of prototype deficiencies.

An accelerated bench test will be devised and performed in the near future to provide a minimum of one thousand closing cycles of the (2) new valve configurations. This test will confirm the correction of the O-ring problem and will permit to assess the relative advantages of the two proposed configurations (oil filled versus pressure case). A demonstration of current meter data telemetry will also be conducted in the immediate future. The current at 3 meters and 15 meters below the surface will be measured by two current meters hanging from the WHOI dock. Automatic transmission of these data to local and standard ARGOS receiving stations will then be controlled and performed by the R-TEAM computer/transmitter electronic system. All components will be those used in the Site D deployment.

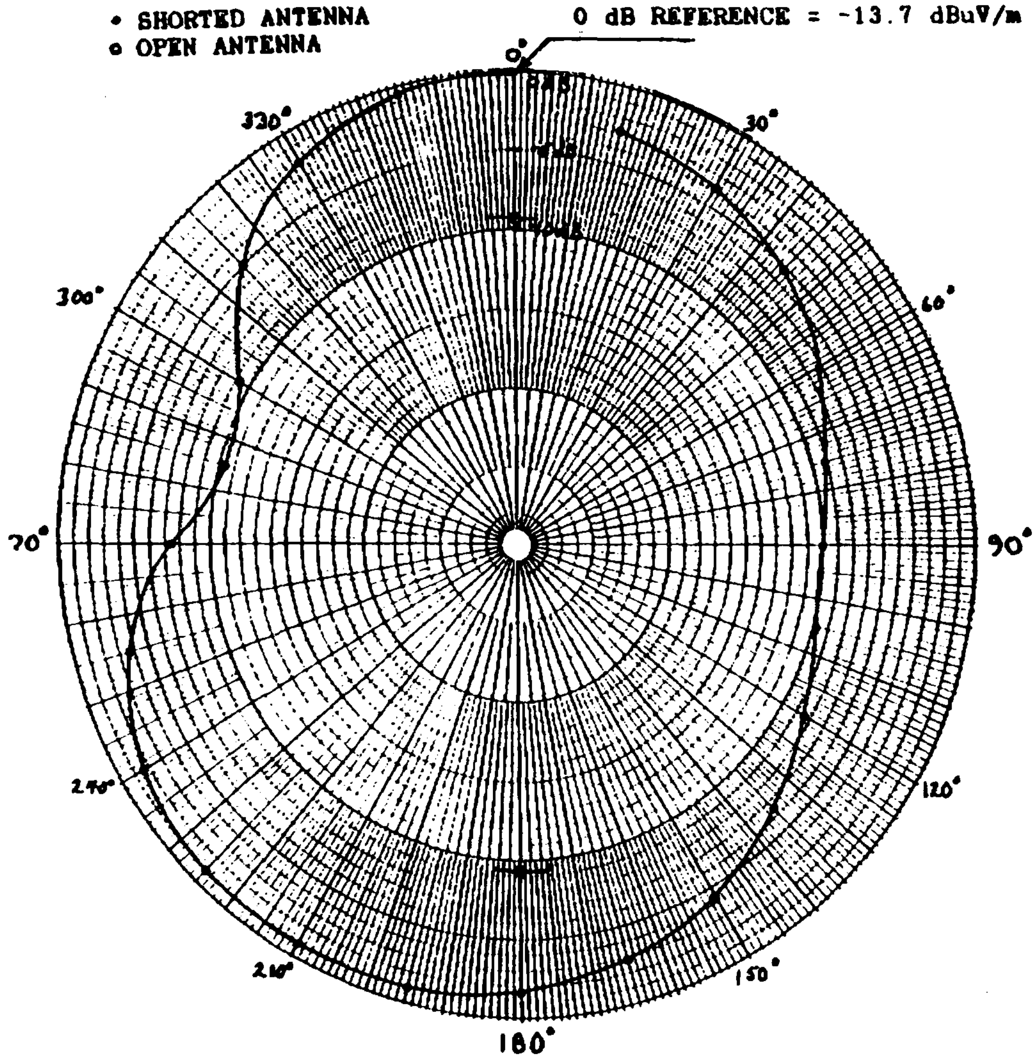
- Refurbish/repair the damaged MF transmitter (DSI)
- Integrate/test both transmission modes. Perform final MF antenna pattern/range tests in Woods Hole (DSI/WHOI).
- Arctic deployment planning. In conjunction with ONR, select the site, schedule, ship and ship equipment for the Arctic deployment.

Select location for shore station. Assign responsibilities of scientific party. Gear shipping provisions.

- Arctic mooring design/procurement/assembly. Because of its new location and depth, a new mooring design will be needed. New components will also be designed and fabricated. In particular a new rugged version of the ascent module needs to be built. New cable assemblies need to be made to accommodate the insertion of additional sensors (ALS). The collar needs to be modified for assembly of an Upward Looking Sonar (ULS). The software needs to be updated and all instruments need to be prepared for one year service.
- Arctic precruise testing. Emphasis will be placed on components, subsystems, and full system testing prior to shipping. Testing environment will be "cold and wet". (3) groups of tests are anticipated: Ascent module controls and repeated performance (Jobs Neck, offshore Woods Hole). Computer and transmitter performance, from WHOI dock, with at least one Cm/hydrophone sensor. Finally, a complete working system (ascent module, controller, umbilical, control collar, sensor and E/M cable assemblies) will be deployed and activated under closely controlled and safe conditions (ship standing by 24 hours/day) (WHOI/DSI).
- Shipping to Tromso, Norway.
- Install shore station (DSI).
- Deployment (WHOI/DSI).

Figure 2 of this report shows a time table for this future work.

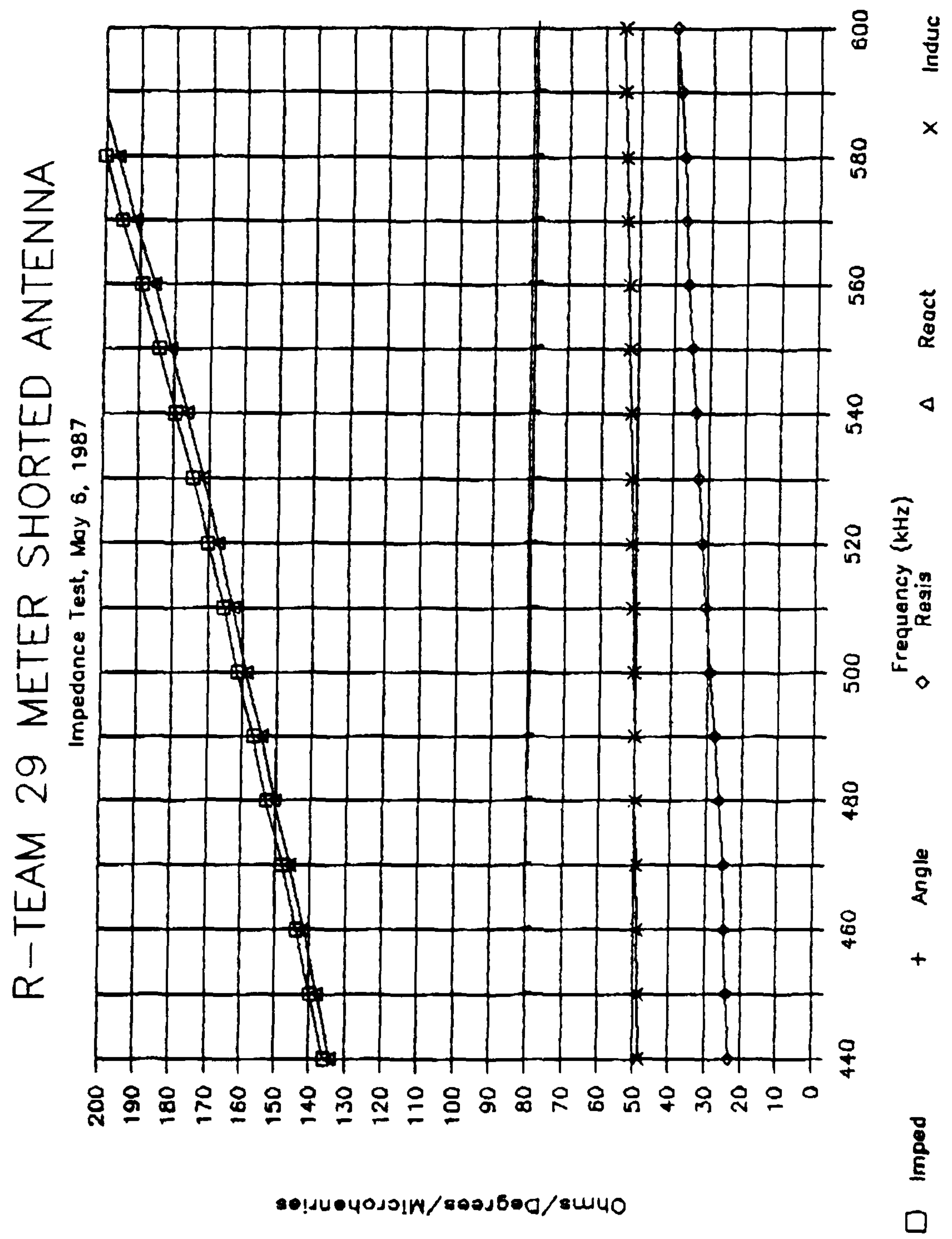
# APPENDICES



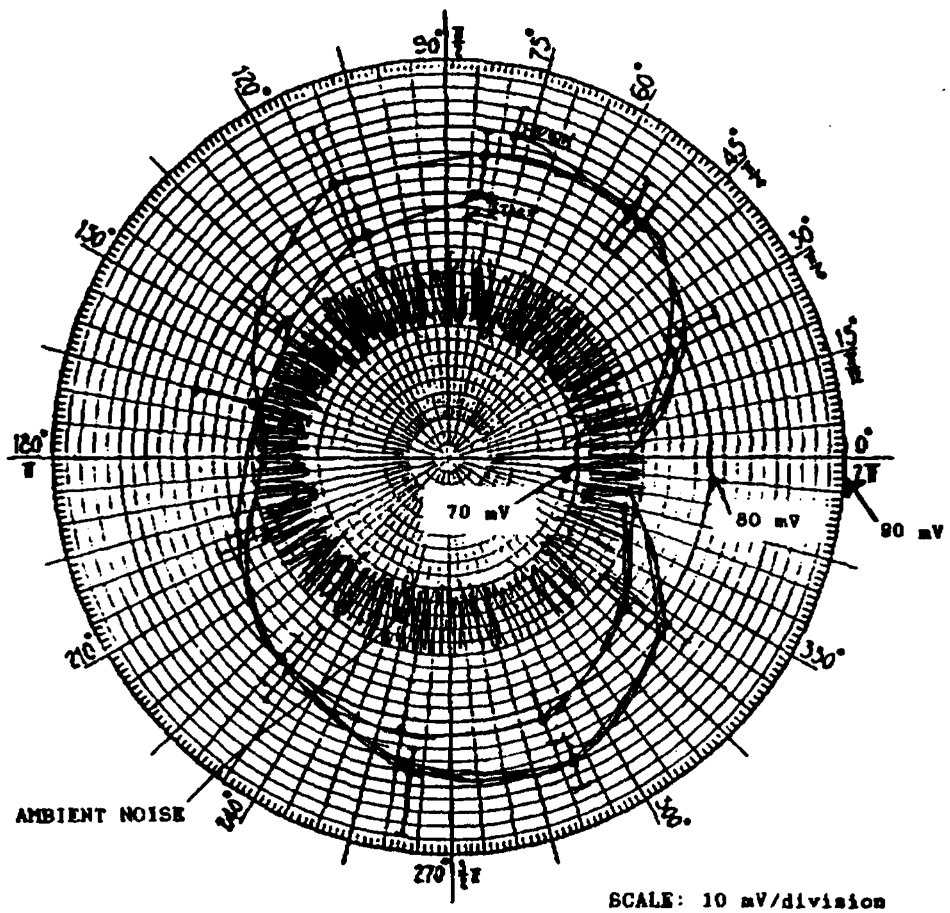

**RTEAM SHORTED ANTENNA FACTOR**

| | |
|---|---|
| **RECEIVED SIGNAL LEVEL** | |
| Measured Sig Level | -13.7 dBuV |
| Rec Antenna Factor | 37.7 dB |
| Rcvd Field Strength | 24.0 dBuV/m |
| Frequency | 522 kHz |
| Frequency Factor | 5.6 dB |
| dBuV to dBm (@1 MHz) | -77.2 dB |
| Equiv Rcvd Power | -47.6 dBm(i) |
| **POWER INTO ANTENNA** | |
| Voltage | 45.0 Vrms |
| Impedance | 4500.0 ohms |
| Phase Angle | 45.0 degrees |
| Delivered Power | 24.6 dBm |
| **PATH ATTENUATION** | |
| Range | 2.0 nm |
| Path Loss | 38.2 dB |
| **ANTENNA FACTOR** | |
| Expected Sig Power | -13.6 dBm |
| Measured Sig Power | -47.6 dBm |
| Antenna Factor | -34.0 dB |

APPENDIX A. 200' FLOATING WIRE ANTENNA: PATTERN AND ANTENNA FACTOR




APPENDIX B1. 29 METER SHORTED ANTENNA IMPEDANCE VS. FREQUENCY




SCALE: 10 mV/division
80 mV = -70 dBm and
3 mV per decibel

R-TEAM
HF LINK CALCULATION
May 6, 1987 Test, 250 Hz BW, High Noise

| | |
|---|---|
| Transmitter Power | 40.0 dBm |
| Trans. Antenna Gain | -34.0 dBi |
| Transmitter EIRP | 6.0 dBm |
| Range | 1.4 nm |
| Range | 2.6 km |
| Frequency | 0.5 MHz |
| Inverse Square Loss | 35.0 dB |
| Path Attenuation | 35.0 dB |
| Field Intensity (dBuV/m) | 42.5 dBuV/m |
| Ambient Excess Noise | 116.0 dB |
| Receive Antenna Factor | 3.5 dB |
| Receiver Input Power | -88.0 dBm |
| Rcvr Equiv Noise Factor | 77.0 dB |
| Receiver Noise BW | 0.3 kHz |
| Receiver Noise Level | -73.1 dBm |
| Pre-detection SNR | 5.0 dB |

APPENDIX B2. 29 METER SHORTED ANTENNA: PATTERN AND ANTENNA FACTOR

# APPENDIX C
## Site D Telemetry Data

FILE - B:MASTER.DAT TOTAL RECORDS = 168

| DATE | TIME | BATTERY | 38V | 28V | TEMP | INT PR. | EXT PR. | RFU CUR. | SYS CUR. | TYPE |
|---|---|---|---|---|---|---|---|---|---|---|
| 06-05 | 12:43:48 | 0.00 | 0.00 | 28.70 | -73.82 | 10.10 | 2.32 | -.50 | 1.50 | 0.00 * |
| 06-05 | 12:43:48 | 45.84 | 39.25 | 40.12 | 29.10 | 12.15 | 243.02 | 1170.00 | 1170.00 | 1.00 * |
| 06-05 | 12:43:48 | 44.65 | 33.86 | 28.70 | 20.30 | 10.10 | 140.54 | 0.00 | 2.00 | 2.00 * |
| 06-06 | 21:30:00 | 0.00 | 0.00 | 28.62 | -73.70 | 9.96 | 2.44 | -.50 | 2.00 | 0.00 |
| 06-06 | 21:30:00 | 45.86 | 34.78 | 40.14 | 28.90 | 12.16 | 283.28 | 1161.00 | 1161.00 | 1.00 |
| 06-06 | 21:30:00 | 44.67 | 34.14 | 28.64 | 20.80 | 10.06 | 110.53 | 104.00 | 32.00 | 2.00 |
| 06-07 | 00:30:00 | 0.00 | 0.00 | 28.62 | -73.70 | 10.09 | 137.01 | -.50 | 2.00 | 0.00 |
| 06-07 | 00:30:00 | 45.86 | 39.17 | 40.14 | 21.10 | 12.16 | 279.14 | 1144.00 | 1144.00 | 1.00 |
| 06-07 | 00:30:00 | 42.88 | 33.63 | 28.62 | 19.00 | 10.09 | 118.83 | 28.50 | 22.00 | 2.00 |
| 06-07 | 12:00:30 | 0.00 | 34.72 | 28.58 | 19.20 | 9.94 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-07 | 12:00:30 | 45.84 | 39.25 | 28.62 | 28.40 | 10.22 | 199.47 | 239.50 | 67.00 | 1.00 |
| 06-07 | 12:00:30 | 44.65 | 34.10 | 28.58 | 19.20 | 9.93 | 161.04 | 0.00 | 2.00 | 2.00 |
| 06-08 | 07:36:43 | 0.00 | 34.72 | 28.54 | 18.90 | 9.89 | 2.56 | -.50 | 1.50 | 0.00 |
| 06-08 | 07:36:43 | 45.86 | 39.29 | 28.62 | 28.30 | 10.24 | 234.97 | 239.50 | 67.00 | 1.00 |
| 06-08 | 07:36:43 | 44.67 | 34.72 | 28.54 | 18.90 | 9.89 | 217.65 | 0.00 | 1.50 | 2.00 |
| 06-08 | 11:38:44 | 0.00 | 34.72 | 28.54 | 19.00 | 9.92 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-08 | 11:38:44 | 45.86 | 38.39 | 28.58 | 27.80 | 10.19 | 235.95 | 240.00 | 66.50 | 1.00 |
| 06-08 | 11:38:44 | 44.67 | 34.72 | 28.54 | 19.00 | 9.89 | 206.79 | 0.00 | 2.00 | 2.00 |
| 06-09 | 07:25:53 | 0.00 | 34.72 | 28.50 | 18.70 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-09 | 07:25:53 | 45.86 | 39.29 | 28.58 | 27.90 | 10.21 | 246.68 | 769.50 | 228.00 | 1.00 |
| 06-09 | 07:25:53 | 44.67 | 34.72 | 28.50 | 18.70 | 9.88 | 186.66 | 0.00 | 1.50 | 2.00 |
| 06-09 | 12:56:57 | 0.00 | 0.00 | 28.48 | -73.82 | 9.89 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-09 | 12:56:57 | 45.86 | 39.17 | 40.12 | 27.70 | 12.15 | 243.02 | 1155.00 | 1155.00 | 1.00 |
| 06-09 | 12:56:57 | 43.89 | 34.54 | 28.48 | 19.00 | 9.91 | 212.89 | 0.00 | 2.00 | 2.00 |
| 06-10 | 07:15:02 | 0.00 | 0.00 | 28.46 | -73.90 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-10 | 07:15:02 | 45.86 | 39.35 | 40.10 | 27.80 | 12.15 | 281.94 | 1155.50 | 1155.50 | 1.00 |
| 06-10 | 07:15:02 | 44.67 | 34.70 | 28.46 | 19.10 | 9.88 | 194.35 | 0.00 | 2.00 | 2.00 |
| 06-10 | 12:35:22 | 0.00 | 0.00 | 28.46 | -73.82 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-10 | 12:35:22 | 45.84 | 39.33 | 40.12 | 27.60 | 12.15 | 281.58 | 1154.00 | 1154.00 | 1.00 |
| 06-10 | 12:35:22 | 43.44 | 34.54 | 28.46 | 19.00 | 9.90 | 200.57 | 0.00 | 2.00 | 2.00 |
| 06-11 | 07:04:11 | 0.00 | 34.70 | 28.42 | 19.00 | 9.87 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-11 | 07:04:11 | 45.84 | 39.33 | 28.48 | 27.50 | 10.17 | 255.47 | 238.50 | 67.00 | 1.00 |
| 06-11 | 07:04:11 | 44.65 | 34.70 | 28.42 | 19.00 | 9.87 | 229.48 | 0.00 | 2.00 | 2.00 |
| 06-11 | 12:13:44 | 0.00 | 34.72 | 28.40 | 19.10 | 9.87 | 2.56 | -.50 | 1.50 | 0.00 |
| 06-11 | 12:13:44 | 45.84 | 39.25 | 28.46 | 27.50 | 10.15 | 241.80 | 238.50 | 66.50 | 1.00 |
| 06-11 | 12:13:44 | 42.56 | 34.84 | 28.40 | 19.20 | 9.87 | 218.01 | 0.00 | 2.00 | 2.00 |
| 06-12 | 08:34:08 | 0.00 | 34.70 | 28.38 | 18.30 | 9.84 | 2.56 | -.50 | 1.50 | 0.00 |
| 06-12 | 08:34:08 | 45.84 | 39.29 | 28.46 | 27.50 | 10.17 | 289.26 | 756.50 | 67.50 | 1.00 |
| 06-12 | 08:34:08 | 43.40 | 34.70 | 28.38 | 18.30 | 9.84 | 271.94 | 0.00 | 2.00 | 2.00 |
| 06-12 | 11:52:00 | 0.00 | 0.00 | 28.38 | -73.90 | 9.85 | 2.56 | -.50 | 1.50 | 0.00 |
| 06-12 | 11:52:00 | 45.84 | 34.78 | 40.10 | 27.50 | 12.15 | 281.21 | 1152.50 | 1152.50 | 1.00 |
| 06-12 | 11:52:00 | 44.65 | 34.12 | 28.38 | 18.70 | 9.88 | 246.07 | 0.00 | 2.00 | 2.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 06-13 08:23:24 | 42.96 | 34.70 | 28.32 | 18.60 | 9.85 | 279.01 | 0.00 | 2.00 | 2.00 |
| 06-13 11:30:13 | 45.07 | 34.72 | 28.34 | 18.60 | 9.85 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-13 11:30:13 | 45.84 | 34.78 | 28.38 | 27.30 | 10.12 | 287.07 | 763.00 | 67.00 | 1.00 |
| 06-13 11:30:13 | 44.65 | 34.70 | 28.32 | 18.60 | 9.85 | 261.08 | 0.00 | 2.00 | 2.00 |
| 06-14 08:12:38 | 0.00 | 34.70 | 28.30 | 18.10 | 9.84 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-14 08:12:38 | 45.82 | 39.33 | 28.36 | 27.20 | 10.16 | 294.63 | 238.50 | 67.00 | 1.00 |
| 06-14 08:12:38 | 42.50 | 34.84 | 28.30 | 18.10 | 9.84 | 252.66 | 0.00 | 2.00 | 2.00 |
| 06-15 12:26:55 | 0.00 | 0.00 | 28.26 | -73.90 | 9.87 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-15 12:26:55 | 45.82 | 39.31 | 40.10 | 27.60 | 12.15 | 259.37 | 1153.50 | 1153.50 | 1.00 |
| 06-15 12:26:55 | 43.10 | 34.38 | 28.26 | 18.80 | 9.88 | 240.46 | 0.00 | 2.00 | 2.00 |
| 06-16 07:51:06 | 0.00 | 0.00 | 28.22 | -74.00 | 9.87 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-16 07:51:06 | 45.82 | 39.31 | 40.08 | 27.80 | 12.14 | 286.82 | 1154.50 | 1154.50 | 1.00 |
| 06-16 07:51:06 | 44.63 | 34.66 | 28.22 | 18.80 | 9.87 | 231.68 | 0.00 | 2.00 | 2.00 |
| 06-17 07:40:17 | 0.00 | 0.00 | 28.18 | 18.70 | 9.86 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-17 07:40:17 | 45.80 | 39.31 | 40.10 | 28.20 | 10.19 | 293.53 | 761.00 | 67.00 | 1.00 |
| 06-17 07:40:17 | 44.61 | 34.70 | 28.18 | 18.70 | 9.86 | 278.53 | 0.00 | 2.00 | 2.00 |
| 06-17 11:43:30 | 0.00 | 34.70 | 28.18 | 19.00 | 9.86 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-17 11:43:30 | 45.80 | 39.25 | 28.22 | 27.90 | 10.14 | 271.33 | 238.50 | 67.00 | 1.00 |
| 06-17 11:43:30 | 44.61 | 34.70 | 28.18 | 19.30 | 9.86 | 218.87 | 0.00 | 2.00 | 2.00 |
| 06-18 07:29:28 | 0.00 | 34.70 | 28.16 | 18.60 | 9.86 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-18 07:29:28 | 45.80 | 39.31 | 28.22 | 27.90 | 10.18 | 297.19 | 239.50 | 67.50 | 1.00 |
| 06-18 07:29:28 | 44.61 | 34.70 | 28.16 | 18.60 | 9.86 | 286.82 | 0.00 | 2.00 | 2.00 |
| 06-18 13:01:39 | 0.00 | 34.70 | 28.14 | 19.10 | 9.86 | 2.56 | -.50 | 1.50 | 0.00 |
| 06-18 13:01:39 | 45.80 | 39.19 | 28.18 | 29.10 | 10.17 | 289.63 | 239.50 | 67.00 | 1.00 |
| 06-18 13:01:39 | 43.93 | 34.70 | 28.14 | 19.10 | 9.86 | 248.03 | 0.00 | 2.00 | 2.00 |
| 06-19 07:18:37 | 0.00 | 34.70 | 28.12 | 18.80 | 9.85 | 2.56 | -.50 | 1.50 | 0.00 |
| 06-19 07:18:37 | 45.80 | 39.23 | 28.18 | 28.80 | 10.19 | 296.95 | 240.00 | 67.00 | 1.00 |
| 06-19 07:18:37 | 44.59 | 34.70 | 28.12 | 18.80 | 9.85 | 283.04 | 0.00 | 2.00 | 2.00 |
| 06-19 12:40:05 | 0.00 | 34.70 | 28.12 | 18.90 | 9.86 | 2.68 | -.50 | 1.50 | 0.00 |
| 06-19 12:40:05 | 45.78 | 39.29 | 28.16 | 29.00 | 10.17 | 279.87 | 239.50 | 67.00 | 1.00 |
| 06-19 12:40:05 | 43.48 | 34.72 | 28.12 | 19.20 | 9.85 | 241.80 | 0.00 | 2.00 | 2.00 |
| 06-20 07:07:46 | 0.00 | 0.00 | 28.08 | -74.00 | 9.88 | 2.56 | -.50 | 1.50 | 0.00 |
| 06-20 07:07:46 | 45.78 | 39.29 | 40.08 | 29.10 | 12.14 | 291.46 | 1159.00 | 1159.00 | 1.00 |
| 06-20 07:07:46 | 44.59 | 34.70 | 28.08 | 19.00 | 9.88 | 258.64 | 0.00 | 2.00 | 2.00 |
| 06-20 12:18:27 | 0.00 | 34.70 | 28.08 | 19.20 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-20 12:18:27 | 45.78 | 39.27 | 28.12 | 29.00 | 10.18 | 278.65 | 748.50 | 228.00 | 1.00 |
| 06-20 12:18:27 | 42.70 | 34.72 | 28.08 | 19.20 | 9.88 | 262.42 | 0.00 | 2.00 | 2.00 |
| 06-21 08:37:41 | 0.00 | 34.70 | 28.03 | 19.20 | 9.90 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-21 08:37:41 | 45.78 | 39.29 | 28.12 | 29.00 | 10.21 | 270.23 | 239.50 | 67.00 | 1.00 |
| 06-21 08:37:41 | 43.42 | 34.72 | 28.03 | 19.20 | 9.88 | 254.74 | 0.00 | 2.00 | 2.00 |
| 06-21 11:56:47 | 44.99 | 34.72 | 28.06 | 19.40 | 9.90 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-21 11:56:47 | 45.78 | 34.78 | 28.08 | 28.60 | 10.19 | 267.42 | 240.00 | 67.50 | 1.00 |
| 06-21 11:56:47 | 44.59 | 34.72 | 28.03 | 19.40 | 9.88 | 231.92 | 0.00 | 2.50 | 2.00 |
| 06-22 08:26:57 | 0.00 | 0.00 | 27.99 | -74.00 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-22 08:26:57 | 45.78 | 39.31 | 40.08 | 28.60 | 12.14 | 254.00 | 748.50 | 228.00 | 1.00 |
| 06-22 08:26:57 | 43.04 | 34.68 | 27.99 | 19.00 | 9.88 | 244.37 | 0.00 | 2.00 | 2.00 |
| 06-22 11:34:58 | 0.00 | 0.00 | 28.01 | -74.10 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-22 11:34:58 | 45.76 | 34.78 | 40.06 | 29.90 | 12.13 | 283.16 | 1160.50 | 1160.50 | 1.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 06-23 08:16:12 | 0.00 | 0.00 | 27.97 | -74.00 | 9.88 | 2.32 | -.50 | 1.50 | 0.00 |
| 06-23 08:16:12 | 45.76 | 39.27 | 40.08 | 29.90 | 12.14 | 284.75 | 1162.50 | 1162.50 | 1.00 |
| 06-23 08:16:12 | 42.60 | 34.76 | 27.97 | 18.90 | 9.88 | 223.26 | 0.00 | 2.00 | 2.00 |
| 06-23 12:53:13 | 0.00 | 34.70 | 27.97 | 18.90 | 9.92 | 2.32 | -.50 | 1.50 | 0.00 |
| 06-23 12:53:13 | 45.76 | 39.23 | 28.01 | 30.20 | 10.23 | 278.40 | 239.00 | 67.00 | 1.00 |
| 06-23 12:53:13 | 43.72 | 34.70 | 27.97 | 18.90 | 9.88 | 256.44 | 0.00 | 2.00 | 2.00 |
| 06-24 08:05:25 | 0.00 | 34.70 | 27.93 | 18.90 | 9.86 | 2.32 | -.50 | 1.50 | 0.00 |
| 06-24 08:05:25 | 45.76 | 39.27 | 28.01 | 29.90 | 10.23 | 294.75 | 239.00 | 67.00 | 1.00 |
| 06-24 08:05:25 | 44.55 | 34.70 | 27.93 | 18.90 | 9.86 | 240.71 | 0.00 | 2.00 | 2.00 |
| 06-24 12:31:37 | 0.00 | 34.70 | 27.93 | 19.30 | 9.89 | 2.32 | -.50 | 1.50 | 0.00 |
| 06-24 12:31:37 | 45.74 | 39.23 | 27.97 | 29.60 | 10.21 | 273.40 | 741.50 | 229.50 | 1.00 |
| 06-24 12:31:37 | 43.18 | 34.72 | 27.93 | 19.30 | 9.86 | 257.66 | 0.00 | 2.00 | 2.00 |
| 06-25 07:54:38 | 0.00 | 34.70 | 27.91 | 19.00 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-25 07:54:38 | 45.74 | 39.23 | 27.97 | 29.40 | 10.22 | 292.56 | 240.00 | 67.00 | 1.00 |
| 06-25 07:54:38 | 44.55 | 34.70 | 27.91 | 19.00 | 9.86 | 285.36 | 0.00 | 2.00 | 2.00 |
| 06-25 12:09:58 | 0.00 | 34.70 | 27.89 | 19.00 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-25 12:09:58 | 45.74 | 39.27 | 27.95 | 29.30 | 10.19 | 293.65 | 240.00 | 67.00 | 1.00 |
| 06-25 12:09:58 | 42.33 | 34.88 | 27.89 | 19.00 | 9.86 | 278.04 | 0.00 | 2.00 | 2.00 |
| 06-26 07:43:51 | 0.00 | 0.00 | 27.87 | -74.10 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-26 07:43:51 | 45.74 | 39.23 | 40.06 | 29.40 | 12.13 | 293.17 | 1160.00 | 1160.00 | 1.00 |
| 06-26 07:43:51 | 44.55 | 34.70 | 27.87 | 19.10 | 9.88 | 285.97 | 0.00 | 2.00 | 2.00 |
| 06-26 11:48:13 | 0.00 | 0.00 | 27.87 | -74.10 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-26 11:48:13 | 45.74 | 39.15 | 40.06 | 28.80 | 12.13 | 286.94 | 1157.50 | 1157.50 | 1.00 |
| 06-26 11:48:13 | 44.55 | 34.32 | 27.89 | 19.00 | 9.92 | 268.03 | 0.00 | 2.00 | 2.00 |
| 06-27 07:33:01 | 0.00 | 34.70 | 27.83 | 18.90 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-27 07:33:01 | 45.74 | 39.21 | 27.91 | 28.90 | 10.21 | 297.19 | 239.00 | 67.00 | 1.00 |
| 06-27 07:33:01 | 44.53 | 34.70 | 27.83 | 18.90 | 9.88 | 284.63 | 0.00 | 2.00 | 2.00 |
| 06-28 07:22:11 | 0.00 | 34.70 | 27.81 | 18.80 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-28 07:22:11 | 45.72 | 39.23 | 27.87 | 28.00 | 10.21 | 297.92 | 748.50 | 228.00 | 1.00 |
| 06-28 07:22:11 | 44.53 | 34.70 | 27.81 | 18.80 | 9.88 | 277.43 | 0.00 | 2.00 | 2.00 |
| 06-28 12:44:47 | 0.00 | 34.70 | 27.79 | 19.00 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-28 12:44:47 | 45.72 | 39.15 | 27.85 | 28.10 | 10.16 | 296.95 | 239.00 | 67.00 | 1.00 |
| 06-28 12:44:47 | 43.52 | 34.70 | 27.79 | 19.00 | 9.88 | 287.19 | 0.00 | 2.50 | 2.00 |
| 06-29 07:11:19 | 0.00 | 0.00 | 27.77 | -74.20 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 06-29 07:11:19 | 45.72 | 39.19 | 40.06 | 28.60 | 12.13 | 292.92 | 727.50 | 224.50 | 1.00 |
| 06-29 07:11:19 | 44.51 | 34.50 | 27.77 | 18.40 | 9.88 | 275.11 | 0.00 | 2.00 | 2.00 |
| 06-30 12:01:27 | 44.93 | 34.70 | 27.77 | 19.40 | 9.91 | 2.56 | -.50 | 1.50 | 0.00 |
| 06-30 12:01:27 | 45.70 | 34.78 | 27.79 | 29.10 | 10.21 | 231.92 | 239.00 | 67.50 | 1.00 |
| 06-30 12:01:27 | 44.51 | 34.70 | 27.75 | 19.40 | 9.90 | 203.25 | 0.00 | 2.00 | 2.00 |
| 07-02 12:57:54 | 0.00 | 34.70 | 27.69 | 19.10 | 9.89 | 2.56 | -.50 | 1.50 | 0.00 |
| 07-02 12:57:54 | 45.68 | 39.17 | 27.73 | 29.90 | 10.21 | 265.23 | 241.00 | 67.50 | 1.00 |
| 07-02 12:57:54 | 43.74 | 34.70 | 27.69 | 19.10 | 9.86 | 247.78 | 0.00 | 2.00 | 2.00 |
| 07-03 08:08:57 | 0.00 | 0.00 | 27.65 | -74.32 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 07-03 08:08:57 | 45.68 | 39.23 | 40.02 | 30.10 | 12.12 | 283.77 | 1163.00 | 1163.00 | 1.00 |
| 07-03 08:08:57 | 42.98 | 34.82 | 27.65 | 18.90 | 9.88 | 233.14 | 0.00 | 2.00 | 2.00 |
| 07-03 12:36:18 | 0.00 | 0.00 | 27.65 | -74.32 | 9.88 | 2.44 | -.50 | 1.50 | 0.00 |
| 07-03 12:36:18 | 45.66 | 39.19 | 40.02 | 30.00 | 12.12 | 283.28 | 1161.00 | 1161.00 | 1.00 |
| 07-03 12:36:18 | 43.28 | 34.36 | 27.65 | 19.30 | 9.91 | 232.41 | 0.00 | 2.00 | 2.00 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 07-04 | 07:58:10 | 45.66 | 39.21 | 27.69 | 30.00 | 10.25 | 281.45 | 239.50 | 67.50 | 1.00 |
| 07-04 | 07:58:10 | 44.47 | 34.70 | 27.63 | 19.20 | 9.88 | 215.21 | 0.00 | 2.00 | 2.00 |
| 07-04 | 12:14:39 | 0.00 | 34.72 | 27.63 | 19.70 | 9.90 | 2.44 | -.50 | 1.50 | 0.00 |
| 07-04 | 12:14:39 | 45.66 | 39.21 | 27.67 | 30.30 | 10.22 | 212.89 | 239.50 | 67.00 | 1.00 |
| 07-04 | 12:14:39 | 42.41 | 34.82 | 27.63 | 19.90 | 9.88 | 196.79 | 0.00 | 2.00 | 2.00 |
| 07-05 | 11:52:56 | 0.00 | 34.72 | 27.61 | 20.30 | 9.93 | 2.56 | -.50 | 1.50 | 0.00 |
| 07-05 | 11:52:56 | 45.64 | 39.09 | 27.63 | 30.00 | 10.17 | 225.09 | 239.50 | 67.50 | 1.00 |
| 07-05 | 11:52:56 | 44.45 | 34.72 | 27.59 | 20.30 | 9.91 | 200.57 | 0.00 | 2.00 | 2.00 |
| 07-07 | 07:25:42 | 0.00 | 0.00 | 27.53 | -74.40 | 9.93 | 2.56 | -.50 | 1.50 | 0.00 |
| 07-07 | 07:25:42 | 45.64 | 39.17 | 40.00 | 29.70 | 12.11 | 283.28 | 1161.00 | 1161.00 | 1.00 |
| 07-07 | 07:25:42 | 44.45 | 34.70 | 27.53 | 19.70 | 9.93 | 227.29 | 0.00 | 2.00 | 2.00 |
| 07-09 | 08:44:41 | 0.00 | 0.00 | 27.45 | -78.00 | 9.92 | 2.56 | -.50 | 1.50 | 0.00 |
| 07-09 | 08:44:41 | 45.62 | 39.17 | 39.27 | 29.90 | 13.73 | 274.50 | 1125.00 | 67.50 | 1.00 |
| 07-09 | 08:44:41 | 43.38 | 34.70 | 27.45 | 19.30 | 9.92 | 204.84 | 0.00 | 2.00 | 2.00 |
| 07-09 | 12:06:09 | 44.83 | 34.72 | 27.45 | 20.20 | 9.92 | 2.56 | -.50 | 1.50 | 0.00 |
| 07-09 | 12:06:09 | 45.62 | 34.78 | 27.49 | 30.30 | 10.25 | 198.37 | 240.50 | 68.00 | 1.00 |
| 07-09 | 12:06:09 | 44.43 | 34.70 | 27.45 | 20.60 | 9.92 | 172.75 | 0.00 | 2.00 | 2.00 |
| 07-10 | 08:33:58 | 0.00 | 0.00 | 27.41 | -74.50 | 9.89 | 2.56 | -.50 | 2.00 | 0.00 |
| 07-10 | 08:33:58 | 45.60 | 39.21 | 39.98 | 30.40 | 12.11 | 274.87 | 239.50 | 128.50 | 1.00 |
| 07-10 | 08:33:58 | 43.16 | 34.70 | 27.41 | 19.20 | 9.89 | 244.37 | 0.00 | 2.00 | 2.00 |
| 07-10 | 11:44:24 | 0.00 | 0.00 | 27.41 | -74.40 | 9.89 | 2.20 | -.50 | 1.50 | 0.00 |
| 07-10 | 11:44:24 | 45.60 | 34.80 | 40.00 | 29.90 | 12.11 | 242.29 | 1161.00 | 1161.00 | 1.00 |
| 07-10 | 11:44:24 | 44.13 | 34.12 | 27.43 | 24.00 | 9.99 | 9.52 | 30.00 | 38.50 | 2.00 |
| 07-11 | 08:30:00 | 40.58 | 34.76 | 27.41 | 21.70 | 10.47 | 2.20 | 4.50 | 10.00 | 0.00 |
| 07-11 | 08:30:00 | 45.19 | 34.82 | 27.43 | 31.30 | 10.67 | 156.53 | 534.00 | 570.50 | 1.00 |
| 07-11 | 08:30:00 | 43.91 | 34.20 | 27.41 | 27.50 | 10.53 | 15.37 | 65.00 | 73.50 | 2.00 |

* 0.00 = Minimum
1.00 = Maximum
2.00 = Average

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**4. Title and Subtitle**

**Real-Time Environmental Arctic Monitoring (R-TEAM) Interim Report**

5. Report Date: November 1987

6.

7. Author(s): Edited by Alessandro Bocconcelli

8. Performing Organization Rept. No.: WHOI-87-50

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Woods Hole, Massachusetts 02543

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16. Abstract (Limit: 200 words)

This interim report describes the development and testing of the R-TEAM system from the initial concept studies to the actual deployment and recovery of a working prototype at Site D, 39° N, 70° W (June 2 to August 3, 1987). The R-TEAM mooring is specifically designed to collect oceanic environmental data in the Arctic region and to transmit these data to shore on a daily basis via ARGOS satellite telemetry. To this end an ascent module comes to the surface once a day and transmits directly to ARGOS (ice free surface) or indirectly through a relatively adjacent MF receiver station (ice covered surface) which in turn relays the data to the ARGOS satellite. When not transmitting, the module remains in its rest position most of the time, well away from the surface, thus diminishing the risks of damage at the ice interface. The design life of the R-TEAM system is one year *in situ*. The mooring must be capable of deployment in depths of up to 4500 meters and must be able to withstand a maximum current speed of 2 knots at the surface.

17. Document Analysis a. Descriptors
1. Moored satellite telemetry buoy
2. Arctic environmental mooring
3. Tethered ascent module

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

| 18. Availability Statement | 19. Security Class (This Report) | 21. No. of Pages |
|---|---|---|
| ... for publication; distribution unlimited. | UNCLASSIFIED | 66 |
| | 20. Security Class (This Page) | 22. Price |

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